ISOKINETIC PROFILE OF TRUNK MUSCLES IN ATHLETES

A QUANTITATIVE STUDY WITH CORRELATION TO SPORTS PERFORMANCE

BY

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CONTENT

ABSTRACT

Trunk muscles are important for general activities and all sports that require abdominal and back strength for stability, bending, pulling and twisting. In addition, trunk muscles also play an essential role in injury prevention. Unfortunately, objective evaluation of the characteristics of trunk muscles is scarce. Isokinetic evaluation is frequently used to assess muscle strength and endurance capacity of athletes among different sports. It provides the researchers with a quantitative written record or profiles of athletes. The main purpose of this study was to determine the trunk extensor and flexor strength and endurance capacity, measured isokinetically, of elite male athletes in Hong Kong.

The sports involved in this study included badminton (n=5), squash (n=7), cycling (n=7), rowing (n=7) and canoeing (n=9). Totally 35 national team athletes participated in this study. Fifty five young non-athletic adults were tested as the control group. There were no significant difference ($p<0.05$) between the athletic and non-athletic group in terms of age, height, weight and % body fat.

All the subjects were tested on a Cybex Trunk Extension/Flexion Testing and Rehabilitation Unit (TEF)™, and the parameters being investigated included peak torque, work, total work, flexion/extension peak torque and work ratios. The constant test speeds used were 60 deg/sec, 90 deg/sec and 120 deg/sec. The isokinetic muscular characteristics of the athletes were compared sport by sport, and with the control group to confirm the muscular differences between athletes among different sports.

Generally, athletic groups showed significantly higher ($p<0.05$) isokinetic strength and endurance capacity than the non-athletic group. Cycling is supposed to be the sport that stress the least on both trunk flexor and extensor, therefore it was reasonable for the cyclists to produce the lowest results in the trunk extension and flexion tests (peak torque (60 deg/sec) : 329 ± 50 Nm (extension) and 216 ± 29 Nm (flexion)). In the trunk extension test, badminton players scored the highest results in nearly all parameters (peak torque (60 deg/sec) : 368 ± 34 Nm (extension)). Accordingly, it seems that the badminton players' trunk extensor are highly involved in the game. On the other hand, the canoeing group was the leading group in trunk flexion test results (peak torque (60 deg/sec) : 304 ± 30 Nm (flexion)) and because of their high score in the flexion test, they got the highest results in trunk flexion/extension peak torque (87.9 ± 17.5 % (60 deg/sec)) and work ratios (96.6 ± 16.2 % (60 deg/sec)), i.e. the strength capacity of the trunk flexor was similar to that of the trunk extensor. Therefore, the balance of the trunk extensor and flexor may be more important for canoeists. Rowers scored superior results in total work measure in trunk extension test (6445 ± 1046 joules (120 deg/sec)), as the strength and especially the endurance capacity of the back extensor is a critical factor for a success rower. In comparison with other test groups, squash was the group that had their flexion/extension peak torque ratios (73.7 ± 14.8 % (60 deg/sec)) closest to the non-athletic group (72.7 ± 11.1 % (60 deg/sec)).

The test results of this project further confirmed that the isokinetic trunk muscular characteristics of elite male athletes among different sports were different.

I. INTRODUCTION

1.1 General Introduction

As a basis of specific training regimes in a sport, one would ideally wish to have a quantitative analysis of the qualities needed in that particular sport. Therefore, in recent years there has been an increasing interest in quantifying the strength performance of peripheral joint muscles for specific sports and numerous studies indicate that there are many characteristics and quantifiable musculoskeletal differences between athletes of different sports. However, information regarding the trunk extensor and flexor is scarce, especially for South East Asian athletes.

The trunk and back are exceedingly complex structures that contribute to performance in most activities. Therefore, a need exists for a better and more objective understanding of the trunk's capabilities with regard to muscular strength, power, and endurance.

Trunk muscle strength is considered to be of vital importance in protecting the spine against back strain during activities of daily life. Morris et al (1) conducted biomechanical studies on the trunk and stressed the importance of the trunk muscles in providing extrinsic stability to the spine. Adequate trunk muscle strength is required to stabilize the lower spinal segment and to distribute forces throughout the entire abdominal and thoracic cavities. Moreover, all sports require abdominal and oblique strength for stability, bending, pulling and twisting (2), and for injury prevention (3). Swimmers' balance and power come primarily from the back, and some strokes, especially the butterfly, utilize mainly back muscles (4). Therefore, abdominal and back muscle training is an important part of the strength training programs for nearly all sports.

Low-back pain cause a loss of 217 million work days a year (5) and 17% of all adults in the U.S. had reported back symptoms at some point during their lives (6). Hause et al (7) stated that weak abdominal muscles are frequently found in patients who have low-back pain, and in an evaluation of 4000 cases of low-back pain patients, trunk muscular weakness was present in various degrees (8). Larson (9) and Klausen (10) have emphasized proper balance of strength between the long flexors and extensors for the prevention and treatment of chronic low back dysfunction. Hause et al (7) found that there was a significant relationship between the strength levels of abdominal muscles and those of back muscles, the ratio of abdominal to back muscles was less than one in most of the subjects they investigated. They also suggested that those who have strong abdominal muscles are apt to have strong back muscles as well. Addison et al (11) found that ratios of back extension to flexion were smaller for patients than for healthy subjects.

As trunk extensor and flexor are important for daily life activities, sporting performance and injury prevention, it is important to have objective functional capacity measurements to quantify trunk muscle characteristics. Functional capacity measurement is one of the critical components for diagnosis and surgical decision making. Smith et al (12) suggested that there is a need for data for specific athletic and occupational groups, which could be used in pre-athletic and pre-employment screening.

Trunk muscle has been assessed isometrically, isotonically, and isokinetically (12). Marras and colleagues suggested that isokinetic torque could quantify the extent of impairment and that results of isometric lifting capabilities might be misleading (13). The isokinetic method has unique advantages in testing various aspects of muscle performance. By controlling velocity, isokinetic exercise allows maximum resistance through the entire range of motion by constantly accommodating to the variation in muscle force output. Because of the control of speed and resistance with isokinetic evaluation, an objective measurement of the muscular characteristics can be obtained. Moreover, several studies have been done to test the reliability and validity of the isokinetic device in measuring torque, work and power (14-17). All of these studies indicate that technical accuracy and reliability of the isokinetic device are very high. Numerous studies using isokinetic (7, 18-20) techniques have been conducted to assess the trunk musculature, generating a wide range of results. Unfortunately, it is difficult to compare results between these studies as there is a wide variation in testing apparatus and testing position. Recently, a stabilization system for trunk muscle force assessment has been developed by Cybex - TEF system, and has become a commercially available tool for assessing trunk strength. As this device become increasingly prevalent, it is useful to build up normative data for a variety of population groups by using TEF.

Sapega et al (21) states that studies done at the Institute of Sports Medicine and Athletic Trauma repeatedly indicate that there are many characteristics and quantifiable musculoskeletal differences between athletes of different sports. The question arises as to whether such differences would occur in trunk muscles. If so, it should be possible to ascertain the trunk muscle characteristics of Hong Kong elite male athletes with respect to different sports. The main purpose of this study was to determine the trunk muscle characteristics, measured isokinetically, of elite athletes of different sports, and young, non-elite athlete male adults in Hong Kong. In addition, an attempt was made to find out whether there were significant differences in muscle characteristics among different sports. The main hypothesis was " The muscular characteristics of elite Hong Kong male athletes, measured isokinetically, are different among athletes of different sports".

The data obtained in this investigation can provide sport-specific data files or profiles that quantitatively document the normal range of physical characteristics and capabilities for well-defined groups of athletes. By profiling appropriate sample population from specific groups of athletes, objective standards and norms for those groups can also be defined. These norms are important in setting goals for strength training and rehabilitation programs. Moreover, isokinetic muscular profiles have considerable application in developing a better understanding of the requirements of a sport and profiling is one of the most common strategies for identifying contributors to skilled performance. Coaches can develop specific weight training programs according to the specific requirements of their own sport. Through specific weight training, athletes (especially young athletes) can develop suitable muscular condition for particular sports. Then, their chances of performing better in their sport will be enhanced while chances of getting sports' injuries will be lowered.

1.2 Operational definitions

1.2.1 Isokinetic parameters being investigated

I) Peak torque (PT), is a measure of force of a rotational movement. Peak torque is indicative of maximal muscular tension capability, taking into account changes due to biomechanical leverage and the muscular length-tension relationship that occurs throughout the range of motion. Torque levels are specific to muscular tension intensity; therefore, torque decreases as angular velocity increases. (unit : Nm)

II) Peak torque/body weight ratio (BWR%), is a measure of relative muscle strength, calculated by dividing peak torque by the subject's body weight. Clinically experience has shown this ratio to be a valuable tool for making interindividual comparisons.

III) Work is derived by multiplying torque by the distance of the total area under the torque curve. The "best work rep" documents the maximum work output over the entire range of motion, and therefore presents a more accurate picture of the patient's ability than simply peak torque (force). (unit : joules)

IV) Work/body weight ratio (BWR%), is a measure of relative muscle work capacity, calculated by dividing work by the subject's body weight.

V) Total work is defined as the sum of work over a preselected number of repetitions. Total work analysis measures muscle function in every repetition at all points in the range of motion, while peak torque analysis only reports muscle function at one point. Total work performed is dependent on the subject's muscular power capability at the test speed, as well as available anaerobic energy stores and pH tolerance in the working muscles. (unit : joules)

VI) Opposing muscle group ratios, are calculated by dividing the flexion score by the extension score (*100), and are expressed as the ratio of flexors to extensors.

1.2.2 Elite athletes

The elite athletes involved in this study, were national Hong Kong team members. The sport teams consisted of badminton, canoeing, squash, rowing and cycling.

1.2.3 Non-athletes

The non-elite athlete, male adults, were healthy young men and did not attend any regular training. All these subjects were volunteers.

1.2.4 Fast twitch and slow twitch muscle fibres

There are two main types of muscle fibers found in human skeletal muscle: Fast twitch fibers (FT) which have high anaerobic and low aerobic capacity, i.e. these muscle fibers can do higher power work for a short duration, and slow twitch fibers (ST) which have high aerobic and low anaerobic capacity, i.e. these muscle fibers can do low power work for a long period of time. During exercise, there is preferential recruitment of fiber types: slow twitch fibers during endurance exercise, and fast twitch fibers during sprint like exercise (22).

1.3 Assumptions

The five sports being investigated were at the time of the study, the most popular sports in Hong Kong and the national athletes of these sports had good results in Asia and internationally. Even though all these national athletes were non-professional or were just semi-professional, they had spent quite a long time training intensively in their specific sport and had participated in many competitions. Therefore, they were expected to have acquired muscular adaptation to their specific sport. As a result, it was expected that the test results would reveal specific characteristics produced by these particular sports. Sixty young, non-elite, male athlete subjects served as a control. It was assumed that the test results of this group could reveal the non-elite athletes' trunk muscle characteristics.

1.4 Limitation and delimitation

In addition to the specific physical training effect on trunk muscle strength, power and endurance, several other factors affect such muscle characteristics. These factors include genetics, sex, age and body weight. To ensure that the sport specific isokinetic muscular characteristics differences were mainly due to the specific physical training effect, all the above listed factors except genetic factors were controlled.

1.4.1 Genetic factor

Fast and slow twitch muscle fiber distribution and genetic factors could not be controlled in this study.

1.4.2 Sex factor

Males are stronger than the female throughout childhood, with the gap widening during adolescence. Males are about 50% stronger than females in most muscle groups (23), including the trunk muscles (12) . Therefore, only male athletes and male non-athletes participated in this investigation, in order to eliminate the sex factor.

1.4.3 Age factor

Peak torque of the knee extensors (tested at 210 deg/sec) increases with age for boys from 13 to 17 years (24). Isometric muscle force is fairly well preserved until about 45 years old. Larsson et al (25) studied 144 male subjects performing the isokinetic knee extension test. Results showed that the extension peak torque increased with age in both the 10-19, and 20-29 year age groups. It remained almost constant in the 40-49 year group, and decreased with age in the oldest group (50-69 years). Nachemson and Lindth (26) found that the variables "trunk extension strength and abdominal strength were independent of age for men (age range : 20-55 years). Fugl-Meyer (27) report that isokinetic plantar flexion torque has no difference between the ages 20-49 years. Because of the practical limitations and in an attempt to eliminate the age factor, the age limit for all non-athletic subjects and athletes in the present study was between 18-28 years.

1.4.4 Body mass factor

Collenlly Maddux et al (28) state that individual body mass and body composition vary, making comparison of maximal absolute muscular performance impractical. Moreover, Troup and Chapman (29) have found that the individual measurements of static strength of the flexor and extensor muscles of the trunk are significantly related to subjects' weight, particularly with male subjects. Therefore, to compare muscular performance of individuals, relative muscular performance can be calculated by dividing the peak torque (peak torque/body weight ratio) by the subject's body weight. Thus, relative peak torque has been suggested to be an important consideration when comparing muscular performance in athletes of different sports (30).

II. LITERATURE REVIEW

The important role of abdominal and back muscles in the supporting ability of the spine has been given much attention, especially in the field of lumbar spine diseases and injuries. Various methods of therapeutic exercises for strengthening those muscles have been proposed by several authors. Although electromyographic and kinesiologic studies have clarified some dynamic features of the trunk muscles, a simple and clinically applicable method of measuring their strength quantitatively, especially for elite athletes, has not yet been developed.

2.1 Dynamic control of trunk extension and flexion

2.1.1 Trunk flexion

The lumbar spine never actually flexes but moves from the extended position of the normal lordosis to a straight anatomical alignment between the vertebral bodies as the body rotates forward relative to the hips in the sagital plane (31).

Trunk flexion incorporates the combined movement of the hip and spine. The anterior trunk musculature includes the rectus abdominus, internal and external obliques, and transverse abdominus. The primary hip flexion musculature consists of the iliopsoas, tensor fascia latae, pectineus and rectus femoris. Trunk flexion against gravity or a resistance involves a powerful contraction of the abdominal and, depending on the position of the hip, the hip flexors (32).

2.1.2 Trunk extension

Lumbar extension from a flexed spinal position involves strong activity in all of the spinal extensor muscle groups accompanied by synergistic activity in the hamstrings and gluteal complexes of both lower extremities (31).

Trunk extension is the result of a dynamic interaction of the hip and spine from a forward flexed position. The hip extensor musculature (the three hamstrings, gluteus maximus, and to a limited extent, the three adductors) is at a mechanically advantageous position early in the extension range of motion. As extension continues, the lever arm at the ischial tuberosity decrease and the hip extensors lose their mechanical advantage. The erector spinae (iliocostalis, longissimus, spinalis) and deep posterior muscles (transversospinalis, interspinalis, intertransversarii, levatores costarum) then gain advantage in completing the motion to full extension. Therefore, the order of recruitment in trunk extension is hamstrings, glutei and, finally, the paravertebral muscles (32).

2.2 Dynamic stabilizers in the movement of trunk extension and flexion

2.2.1 Trunk flexion

It should be noted that functional forward bending is primarily controlled by an eccentric contraction of the trunk extensors (33).

Dynamically, the spinal extensor muscle groups stabilize the lumbar region during flexion activities. The muscles modulate movement ability, in order to minimize the stresses applied to the facet joint in the vertebral column and the other static stabilizers (e.g. ligaments), and counteract the force of gravity as it acts to rotate the body forward in the sagital plane (31).

2.2.2 Trunk extension

During extension, the abdominal muscle groups continue to function in their role as a hydraulic amplifier to elicit a sufficient degree of intra-abdominal pressure and an efficient degree of thoracolumbar fascial tension to stabilize the extending spine against external forces and to protect the intervertebral discs (34-36).

2.3 Importance of trunk muscle strength to sports performance

Pauletto (2) states that all sports require abdominal and oblique strength for stability, bending, pulling, and twisting.

Movement of the trunk is an important contributor to the efficient performance of sports skills. Flexion and extension of the vertebral column assist in the production and transfer of forces and allow the athlete to make significant changes in the position of the center of gravity (37).

Well developed strength in muscles controlling the trunk is important in many sport contexts. Most sports encompass relatively large movements of the trunk. Since the trunk segment has a large mass, greater demands are exerted on the trunk musculature, particularly if the trunk movements are to be performed with high accelerations. Also, the trunk has a critical role for the maintenance of stability and balance when performing movements with the extremities (38).

Broccoletti (4) has summarized the importance of the back muscles to several sports :

> "Your back is one of the three crucial areas of your body in football. It is subjected to pounding and needs to be built up to prevent injuries. It also needs to be strong for your blocking and tackling (these are grappling muscles). For real power, you need to have a strong back. Strong latissimus dorsi (lats) also help the quarterback throw.
>
> In basketball, your back takes a constant pounding from the hard court. You need to build up your lower back to prevent injuries; strengthening your back will help to give you power under the boards.

Baseball catchers have numerous back problems due to their stance. These problems can partially be prevented by building up your lower back. All players but, especially pitchers and catchers, need strong lats to help in throwing.

Soccer players' backs also take a pounding which can be helped by preventive weight-training exercise. Goalies especially use lots of back work for catching balls.

Swimmers' balance and power comes principally from the back, and some strokes - especially the butterfly - utilize mainly the back muscles.

Wrestlers can both prevent back injuries and improve their power and explosives by building up their backs. Developing the lower back will help defend against the cradle, standups, and cross-body rides. With great lat strength, you will be able to squeeze the breath out of your opponent. They are tackling and grappling muscles.

Bodybuilders need a wide back for both the lat spread and general appearance. But they must not neglect the lower back both for their health and looks. They have to be very serious about developing all parts of the back so they need to do a variety of back exercise."

2.4 Importance of trunk muscle strength in injury prevention

Optimal function of the human spine requires that it be flexible, yet strong enough to withstand functional loads. The conflicting nature of these requirements may be a contributing factor in spinal dysfunction (39).

McNeil et al (40) measured the trunk muscle strength in 27 healthy males and 30 healthy females, and in 25 male and 15 female patients with low back pain and/or sciatica. Maximum voluntary isometric strengths were measured during attempted flexion, extension, and lateral bending from an upright standing position. They calculated that isometric extension during attempted trunk extension was more limited by existing low-back conditions than were exertions during attempted flexion or lateral bending.

The above study indicated that muscle weakness existed in the back extensors for the low-back pain patients. On the other hand, some other studies reveal different results.

Nachemson and Lindh (26) measured static abdominal and back muscle strength with and without low back pain. This study had revealed that at least for men a relative weakness of the muscles was of minor, if any, importance for the pathogenesis for low-back pain and they doubted that the importance of the strong spinal and abdominal muscles for the prevention of low-back pain syndrome. They also stated that the reduced strength noted by other studies in low-back pain patients was more likely to be the result of prolonged inactivity.

The values of maximum muscle torque of low-back pain patients were significantly lower than those of the male and female normal subjects. The maximum isokinetic torque of the patient group was below the minimum of the normal male population, but this was not true in the case of maximum isometric torque. This implies that maximum isokinetic torque is significantly different in normal and patient groups (19).

Therefore, it seems that isometric strength measurement of trunk muscles may not be sensitive enough to reveal the weakness of these muscles groups in low-back pain patients, while the isokinetic measurement may do so.

Fenety and Kumar (41) studied isokinetic trunk strength and lumbosacral range of motion in elite female field hockey players with reported low-back pain. They reported that the players who complained of low back pain had a significantly reduced lumbosacral extension and total range of motion, when compared to normal women and normal hockey players. They also commented that, regardless of the absence of any low-back pain, female field hockey players should be considered at risk, if they had reduced lumbosacral extension strength or range of motion.

As the isokinetic muscle test worked well in assessing the trunk extensor and flexor, especially in the low-back pain patients, a special isokinetic device has been designed for this purpose.

Smidt et al (42) employed the Iowa Trunk Dynamometer to assess the abdominal and back extensor strength and endurance between normal subjects and low-back pain patients. They found that for peak abdominal and back extensor strength, the range of superiority of normal over patients with chronic low-back dysfunction was 48-82%. Using time, the percent decrement of peak strength, as a criterion, the normal subjects scored lower than those patients who were able to perform dynamic reciprocal trunk movements.

Therefore, Flint (43) has suggested that by increasing the power of the back and abdominal musculature, symptomatic relief from chronic recurring low back pain might be obtained.

2.5 Measurement of trunk muscle characteristics

As Bale and Goodway (44) indicate, it is important to have a method to accurately measure the muscle characteristics. An impressive corpus of literature exists on the measurement of trunk strength in normal subjects and in patients with low-back pain. Various positions (standing: 11, 13, 26, 29, 40, 41; prone and supine: 7, 20, 26; side-lying: 8; sitting : 19, 29, 42), methods (isometric: 8, 11, 13, 19, 26, 29, 40, 42; isokinetic: 7, 8, 13, 19, 20, 41, 42; isotonic: 43), and procedures have been used to measure trunk strength. Studies have yielded results as variable as the tests used.

There are, in a physiological sense, only four ways in which the contractile elements of muscle can produce force through the various bony levers available in the human body. They are (A) isometric contraction (a static contraction); (B) concentric isotonic contraction (shortening); (C) eccentric isotonic contraction (lengthening); (D) isokinetic contraction in which angular velocity of the limb segment is constant.

2.5.1 Isometric contraction

In an isometric, or static contraction, muscle develops tension, but no movement takes place. Since the velocity is held constant at zero, resistance automatically varies to match the force applied. In isometric tests, strength is measured as the peak force or torque developed during a maximal voluntary contraction. Measurement of isometric tension is done quickly, easily and fairly precisely. As most sport movements are dynamic rather than static, the isometric method is not a good method to asses the muscle characteristics of athletes (45).

2.5.2 Concentric isotonic contraction

In concentric isotonic contraction, the muscle shortens with varying tension while lifting a constant workload. In isotonic tests, strength is measured as the heaviest weight which can be lifted once (one repetition) through the range of movement. The most widely used method is the weight lifting method. The apparatus used for weight lifting tests may consist of "free" weights or weight machine (46). Moreover, as Herbert A. deVeries (46) points out, that the isotonic method is not an objective measurement, and consequently not often used for scientific purposes.

2.5.3 Isokinetic contraction

Isokinetic loads involve a fixed speed with variable resistance which accommodates the muscle's ability to generate force. They are characterized by constant velocity at a preselected rate. Resistance varies to match the exact torque force applied through the range of movement as the single highest torque output of the joint produced by a muscular contraction as the limb moves through its range of motion (45). "Cybex" (Lumex, Inc. Ronkonkoma, NY) is a commercially available isokinetic dynamometer. It has been widely used in research, clinical testing, and rehabilitation to objectively assess factors of muscle performance. Recently, a stabilization system for trunk muscle force assessment has been developed by Cybex, named TEF (trunk extension and flexion) system. In recent years, the measurement of strength under conditions of constant velocity of muscular contraction, i.e. the isokinetic method, has become popular (47).

2.5.3.1 Reliability and validity

Reliability and validity of the isokinetic device has been established in several studies.

Bemben et al (15) evaluated the technical accuracy of the Cybex II isokinetic dynamometer and concluded that the velocity of the Cybex II lever arm was well controlled under all conditions. Overall, the actual measured velocities did not differ significantly ($p>0.05$) from the Cybex speed selector settings.

Montgomery et al (14) did a reliability test on the Cybex isokinetic dynamometer. The protocol included a five velocity spectrum torque test. No significant within-subject test differences were noted at any velocity and reliability was generally higher at slower velocities. Total work showed little variability in repeated tests.

Magnusson et al (17) concluded that over a clinically relevant period, intraday and interday correlation coefficients were high for isokinetic shoulder abduction and adduction test. There were no significant differences between values from one day to the next.

Johnson and Siegal (48) investigated isokinetic knee extension using a test-retest protocol over a three day period and reported correlation coefficients of 0.93 to 0.98.

2.5.3.2 Advantage

The Cybex system has been in use for a number of years. Reliability and safety are well established for the Cybex system. Therefore, many studies have been conducted using isokinetic devices. Imwold et al (49) stated that isokinetic testing was useful in quantifying muscular performance. Baltzopoulous and Brodie (50) concluded that the advantages of isokinetic system generate variable resistance equal to the applied muscular force, and constant preselected velocity of movement. These unique features provide safety when used for rehabilitation of patients with muscular and ligamentous injuries and accuracy in the assessment of muscular performance at different functional velocities moments.

2.5.4 Methods that had been used for quantification of trunk strength

Diverse method for measuring trunk strength for both static and dynamic conditions have been recently reported. However, there are several methodological problems in the measurement of trunk muscle strength. Factors that have to be considered are, for instance, the effects of gravity on the trunk, variations in strength due to trunk position and the effects of movement velocity.

In a study by Suzuki et al (20), subjects were placed in a prone and supine position for the acquisition of trunk strength and endurance measures for flexion and extension respectively. A dynamometer moving at constant angular velocity was used to obtain the torque measurement.

With normal subjects in the sidelying position, Smidt et al (8) stabilized the pelvis and lower extremities and determined that strength of the trunk flexor and extensor was dependent on position of the trunk and type of muscle contraction. The subjects demonstrated the greatest strength for a lengthening contraction; static contraction was next in rank, and the least strength was found for the shortening contraction. Muscle strength was found to be related to muscle length so that the flexor-extensor strength ratio was dependent on the position of the trunk.

Marras et al (13) tested ten male and ten female subjects for their ability to exert maximal force about the lumbo-sacral junction under controlled isometric and isokinetic conditions. They found that all trunk muscles were active under both isometric and isokinetic lifting conditions but both the latissimus and erector spinae muscles exhibited dramatically different response patterns between isometric and isokinetic exertion.

Flint (43) assessed average strength in the abdominal and back musculature using the free weight method (one lift, maximum strength). The tests were performed on a specially designed table with the pulley and weight arrangement attached to the wall at the rear of the table. Through the centre of one end of the table top was a slot through which the rope from the pulley could be attached to the "vest-harness" worn by the subject. The table top was also hinged at one end in the middle and free at the other end so that it should be elevated in the centre, pyramid fashion, to permit correct body position when performing the back extension movement. Trunk flexion movement was performed at the supine position.

Smidt et al (42) employed the Iowa Trunk Dynamometer to assess the abdominal and back extensor strength and endurance between normal subjects and low-back pain patients. The Iowa Trunk Dynamometer consists of five major components: mainframe, movable stabilization seat, rotating trunk pads, Cybex II, and the control assembly. With a series of adjustable pads about an adjustable seat, the pelvis, lower extremities, and feet are stabilized. The subject assumed the sitting position in the seat and the foot support was adjusted to the proper height. Rigid pads were placed in firm contact with the anterior shank, anterior thigh, anterior-superior-iliac spines, and just below the level of L5-S1 interspace.

A stabilization system for trunk muscle force assessment has been developed by Cybex. The prototype for this system has been used for evaluating the isokinetic variables, for general population and low-back pain patients, of trunk flexion and extension at different speeds of contraction (12, 18, 51, 52). This system has previously been established as providing reliable measurements (r=0.923) in a test/retest design (53). Moreover, Smith et al (12) stated that measurements for intratest and test-retest consistency were reliable for this prototype.

2.6 Isokinetic trunk muscular characteristics for sports

The present information on trunk muscle strength in athletes is scarce. A literature search revealed only three studies which have been published on this issue.

Andersson et al (38) measured the maximal voluntary strength of the trunk muscles in 57 male, elite athletes (soccer players, wrestlers, tennis players, and gymnasts), 14 female, elite gymnasts, and in a normal group of 87 conscripts. An isokinetic technique was used to record maximal torque produced by trunk and hip muscles during flexion, extension and lateral flexion over the range of motion. The measurements were made with the subjects in a horizontal position with the pivot point at the hip and at the lumbar (L2-L3) level. Differences were present between the athletes and the non-athletes, some of which appeared to be sport specific and related to long-term systematic training. The selective increases of the strength in certain hip and trunk muscles resulted in abnormal strength ratios in some cases similar to those earlier reported for back patients.

Fenety and Kumar (41) conducted a study to compare lumbosacral sagital range of motion and isokinetic trunk strength in three groups of women: 1) athletes with a history of chronic LBP (low-back pain), 2) pain-free athletes, and 3) an age-matched, healthy non-athletic group. Eccentric and concentric isokinetic trunk flexion and extension torque were measured in sitting through 60 deg of trunk movement using an isokinetic dynamometer set at 60 deg/sec. Only peak and average eccentric extension torque were weaker in the pain group than in the non-athletic group.

Cale-Benzoor et al (54) determined isokinetic norms for trunk flexion and extension in classical ballet dancers. Strength levels were determined by peak torque. A fatigue index was derived from 20 reciprocal contractions. Twenty-three dancers were tested-17 females (F) and six males (M). Female dancers were further divided into professional (FP) and semi-professional (FSP) groups. T-tests were performed on peak torque and fatigue data grouped by gender and dance status. Peak torque analysis indicated trends of M>F and FP>FSP. A statistically significant ($p<0.05$) difference existed for trunk extension between FP and FSP dancers, a possible sport-specific adaptation.

2.7 Sport specific muscle characteristics profile

Isokinetic evaluation provided the researchers with a quantitative written record of the torque, and total work develop about a joint throughout the whole range of motion. Such testing has become a standard method of testing various athletic population for muscular strength, power and endurance in sports medicine clinics through many countries. The written records of each sport can be complied to build a norm or profile for each sport.

Sapega and Nicholas (55) stated that sport specific profiles or data files, that quantitatively document the normal range of physical characteristics and capabilities for well defined groups of athletes might lead to abnormal and/or deficient test results which could be objectively identified by comparison. Moreover, the musculoskeletal profile data could also play a significant role in the objective determination of specific rehabilitation goals and return-to-play criteria.

Edward and Vitti (56) commented on the use of muscular profiles that compared an individual's strength measures with a profile of strength characteristics for a similar group of athletes. This might indicate that additional training was necessary to bring that athlete in line with typical performance on such measures. Therefore, by profiling appropriate sample population from specific groups of athletes, objective standards and norms for these groups can be defined. The isokinetic muscular profiles could assist in developing a better understanding of the requirement of a sport and identifying contributing factors to skilled performance.

2.8 Summary

In this chapter, several topics were reviewed. Previous studies have described the dynamic control of trunk extension and flexion movements and also the dynamic stabilizers in these movements. The importance of the trunk muscle strength to sports performance and back injury prevention have been confirmed by many coaches and clinicians. Different methods have been employed to quantify trunk muscle strength. Among these methods, isokinetic test has been classified as one of the best ways to describe the muscular characteristics of athletes from different sports.

Isokinetic evaluation provide written records for each sport, which can build up a norm or profile for each sport.

III. MATERIAL AND METHOD

3.1 Project design

3.1.1 Subject

(A) Athletes :

All the athletes were national team members in Hong Kong. The sports involved in this investigation included badminton, canoeing, cycling, squash and rowing. These sports are common in Hong Kong and the national team athletes of these sports had achieved quite good results in Asia and internationally. Moreover, there is specific trunk muscle involvement in these sports. For example, squash players rotate the trunk with the back in a flexing posture during the game, while canoeing players rotate the trunk with the back in an up-right position. In addition, the degree of exertion, and the extent of trunk rotation differ among these sports. Tests were conducted in the mid-season of each particular sport. The number of athletes included in each sport is listed in Table 3.1.

Table 3.1 Number of athletes in each sport.

SPORT	No. of athletes
Badminton	5
Squash	7
Cycling	7
Rowing	7
Canoeing	9

A total of 35 athletes participated in this investigation.

B) Non-athletic young adults :

Fifty five male subjects served as the control group. They were openly recruited from a medical clinic and Hong Kong post secondary colleges. They had never been on regular training before. This group's results were compared with the athletes' results in order to identify the training and competition effect on the athletes' trunk muscles. The age range of the non-athletic group was matched with the age range of the athletes. Thus, males within the 18 to 28 years range were selected.

All subjects, athletes and non-athletes, were required to sign a consent form (Appendix A). Individuals with know cardiovascular, neuromuscular and muscles problems were excluded from the study, as were those with previous spinal surgery. Also excluded were those who with the previous three years had been bed-ridden for at least one day, due to back pain.

3.1.2 Equipment

A Cybex Trunk Extension/Flexion Testing and Rehabilitation Unit (TEF™) (Cybex Corporation, 2100 Smithtown Avenue, Ronkokoma, NY 11779) was used for data acquisition. The construction features of the Cybex isokinetic spinal dynamometer have not been published, but apparently consist of a small DC servomotor employing tachometer feedback. The Cybex allows torque to be applied and measured in two opposite directions; that is, the shaft of the dynamometer can rotate clockwise and anti-clockwise. A notable safety feature of the Cybex is that the shaft does not rotate with the motor. The shaft must be accelerated (by the subject) and will engage the servomotor. In fact, engagement occurs when the subject attempts to accelerate the shaft beyond the preset velocity of the servomotor (45). The standard subject stabilization system of the TEF was used to fix the subject on the TEF.

The TEF was calibrated according to the guidelines of the manufacturer prior to each data collection session. A Monark 829E electronic bicycle ergometer (Monark Crescent Ab. Varberg, Sweden) was used for subject warm up prior to each testing session.

A Harpenden skinfold caliber (British Indicators Ltd., England) was used to assess the skinfolds of all subjects. Percent body fat for each individual was estimated by summing the measurements of three sites (chest, abdominal and thigh) (57).

3.1.3 Procedures

Subject data collection was accomplished within one session. After giving informed consent, subjects' weight, height and three sites skinfold (chest, abdominal and thigh) were measured. The test session consisted of subject warm up, stabilization, and performance components. Warm up consisted of a 10 minute period of cardiovascular preparation with the Monark bicycle ergometer. Activity occurred at a setting of 60 rpm and a workload (watts) equal to the subject's own body weight (kg). This was followed by a 10-minute general stretching exercise with the emphasis on trunk muscles. The warm up session was used to ensure a sufficient magnitude of physiological preparation prior to the testing effort of each subject.

Stabilization involved placing of each subject into the TEF apparatus using the standard stabilization system. The dynamometer machine axis was centered at the L5-S1 intervertebral segment. The shoulder girdle complex of each subject was stabilized in order to minimize the potential contribution of upper extremity muscle groups to the lumbar and lower extremity muscle performance efforts. The lower body was completely stabilized in a slightly bent-knee position by tibial, popliteal and thigh pads, and a pelvic belt. Starting posture for testing was located at biomechanically-derived anatomical zero. This positioning and stabilization ensure safety, and can be accurately reproduced.

During each data collection session, subject testing consisted of an isokinetic preparation and then a performance period at the speed of 60 deg/sec, 90 deg/sec and 120 deg/sec. Isokinetic preparation involved three gradient submaximal flexion/extension repetitions plus one maximal effort and was immediately followed by four maximal flexion/extension repetitions at 60 deg/sec and 90 deg/sec, and 20 repetitions at 120 deg/sec. There was a 30 second rest period between maximum workout of different testing speeds. The subjects were tested through a motion arc of -15 - 60 degrees from a vertical starting point: flexion from vertical to a position of 60 degrees from vertical, and extension from 60 degrees from vertical to -15 degrees from the vertical (i.e. moving backwards).

The isokinetic measures that were tested and statistically analyzed included peak torque, work and antagonist to agonist muscle peak torque, and work ratio at all test speeds; total work of 20 repetitions at 120 deg/sec.

3.2 Data analysis

A) A dBase IV™ database program was used to store the testing results and SPSS/PC+™ (ver. 3.0) was used to perform all statistical analysis.

B) The statistical analysis consisted of descriptive and analytical procedures. The mean and standard deviation were calculated for the isokinetic measures listed above.

C) One way ANOVA with Scheffe post hoc comparison with a level of significance set at $p<0.05$ was used for comparison between each sporting group and non-athletic group.

3.3 Summary

The Cybex TEF machine was used in this project to assess the trunk muscle characteristics of elite athletes and non-athletic young adults. Both non-athletes and elite athletic groups performed trunk extension and flexion movement tests to evaluate the muscle groups around the trunk. In each movement test, one low speed (60 deg/sec), one medium speed (90 deg/sec) and one high speed (120 deg/sec) were used. The isokinetic test results of the athletes were compared with non-athletics subjects to confirm the training and competition effect on muscles. Moreover, the test results of the athletes were compared sport by sport to confirm the specific muscular requirements in different sports.

IV. RESULT

4.1 Physical characteristics of the subjects

The age, height, weight, % body fat and lean body weight (weight - weight X %body fat/100) measures of subject groups are given in Table 4.1. There were no significant differences ($p > 0.05$) in age , height, weight and % body fat measures. Rowing, canoeing and squash athletes were significantly heavier ($p < 0.05$) than non-athletics subjects in lean body weight measures only. Although it was not statistically significant, the non-athletics subjects were the lightest group and the group with the highest body fat content.

4.2 Trunk extension and flexion isokinetic test result

Mean (standard deviation) of the isokinetic results for the three test speeds of different sports are given in Tables 4.2, 4.3, 4.4, 4.5 and 4.6. and Figures 4.1, 4.2 , 4.3, 4.4, 4.5 , 4.6, 4.7 , 4.8 , 4.9 , 4.10.

4.2.1 Non-athletic group

As there were 52 subjects in the non-athletic group within the age range of 17-29 years, intra-group comparison was carried out to investigate the strength relationships between trunk extensors and trunk flexors. Moreover, the performances of these two muscle groups at the three test speeds were also assessed.

Peak torque and work results, measured across three test speed conditions, were significantly higher ($p<0.05$) in trunk extension movement than in trunk flexion (Fig. 4.1 and 4.2).

Both for trunk extension and flexion movements, peak torque and work results scored at lower movement speed were significantly higher than those at higher speed. Specifically, the results recorded at 60 deg/sec were significantly higher than those recorded at 90 deg/sec. Further, measurements at 90 deg/sec were significantly higher than at 120 deg/sec (Fig. 4.1 and 4.2).

The trunk flexion / extension ratio results increased with test speeds, and the differences between the two high test speeds were statistically significant ($p<0.05$) (Fig. 4.1 and 4.2).

The correlation coefficients of body weight and lean body weight with trunk extension and flexion peak torque and work measures at the three test speeds are listed in Table 4.7. Both body weight and lean body weight were highly correlated with all peak torque and work measures ($p<0.05$).

4.2.2 Badminton group

Badminton athletes scored the highest results in all trunk extension measures, with the exception of peak torque measure at 60 deg/sec, and absolute work and total work measures at 120 deg/sec. The superiority of this group was more obvious in relative (body weight ratio) measures. Therefore, for absolute trunk extension measures, their results were statistically higher than ($p<0.05$) non-athletic group. But for the relative measures (body weight ratio), they produced significant higher results than canoeists and cyclists (in two high speed tests).

For trunk flexion, in terms of all relative measures, the results of the badminton group were just lower than those of the canoeists' and significantly higher than those of the non-athletic group. But in the case of absolute values, their scores were lower than those of the canoeing team, rowing team and squash team, and just significantly higher than non-athletic group at high speed tests, in both peak torque and work body weight ratios.

For the trunk flexion/extension peak torque and work ratios, badminton was comparatively the lowest group and they were significantly lower than canoeists in work ratios at 60 deg/sec and 120 deg/sec.

4.2.3 Squash group

Apart from the absolute peak torque measures in trunk extension movement, the squash players' results were significantly higher than the Non-athletic subjects especially in the high speed tests in both trunk extension and flexion movements. Their results were generally lower than badminton and rowing athletes' in trunk extension movement, and lower than the canoeing athletes' and rowing athletes' results in trunk flexion movement.

The trunk flexion/extension peak torque and work ratios of the squash group were around 74% to 82%, and this range was similar to that of the rowers.

4.2.4 Cycling group

This group scored lower in all measures, in comparison with other sport groups, and even statistically significantly lower than the canoeing group in trunk flexion movement. Their results were comparable to non-athletic group, except in the high speed work and total work measures in the trunk extension test.

4.2.5 Rowing group

In absolute measurement of peak torque and work, this group was just lower than the badminton group in trunk extension movement, and just lower than the canoeing group in trunk flexion movement. As stated before, the rowing group was the heaviest group in this study, their second highest position in relative work measures of trunk flexion test was replaced by the badminton group . In total work and work measures (120 deg/sec), this group had the highest results in the trunk extension test. In general, the results of the rowing group were significantly higher than those of non-athletic group.

Trunk flexion/extension ratios did not increase with speeds. In average, they scored 75.2 % in peak torque ratio and 77.1 % in work ratio.

4.2.6 Canoeing group

In the extension movement test, this group's result was significantly higher ($p<0.05$) than that of non-athletic group, except in relative peak torque measures. On the other hand, canoeists' results were comparatively lower than those of other sport groups. Further, they were even statistically significantly lower than the results of the badminton group in relative measures of peak torque and work.

On the other hand, this group had the best results in the trunk flexion movement test for all measures, and their results were significantly higher than non-athletic and cycling group.

Because of the high scores in the flexion test, canoeists scored highest in trunk flexion/extension peak torque and work ratios, and their results were even significantly ($p<0.05$) higher than those of the badminton group in work ratio at all tested speeds.

4.3 Summary

In this chapter, the isokinetic test results of different groups were presented. In the non-athletic group, it was found that the extension test results were significantly higher than flexion test results. Moreover, the isokinetic values of both movement tests decreased as the test speed increased, and their isokinetic results were highly correlated with body weight and lean body weight. The sport groups generated higher scores than the non-athletic group in nearly all measures, but not all sports had significantly higher results than the non-athletic group. In sports comparison, some sports had nearly all parameters higher than other groups, e.g. badminton team in the extension test, the canoeing team in the flexion test. The flexion/extension peak torque and work ratios were important measures to be identified in different groups. Generally, different groups generated different isokinetic test results.

Table 4.1 : Mean (Standard deviation) age , height , weight , % body fat and lean body weight of subjects .

Subject Groups	Age (yrs)	Height (cm)	Weight (kg)	% Body Fat (%)	Lean Weight (kg)
Non-athletic (N=52)	22.0 (2.6)	171.0 (5.2)	61.3 (8.5)	9.9 (6.0)	55.1 (5.6)
Badminton (N=5)	22.8 (1.3)	172.8 (6.8)	62.0 (3.7)	4.0 (0.4)	59.6 (3.7)
Squash (N=7)	21.3 (2.0)	173.0 (3.8)	67.9 (9.9)	7.1 (5.4)	62.6 * (5.7)
Cycling (N=7)	22.7 (2.7)	172.1 (2.8)	63.1 (4.6)	5.3 (0.7)	59.8 (4.0)
Rowing (N=7)	22.6 (5.8)	175.6 (3.1)	71.6 (2.2)	6.9 (2.0)	66.4 * (3.0)
Canoeing (N=9)	23.1 (6.1)	172.1 (3.6)	69.0 (7.5)	7.9 (3.5)	63.4 * (5.0)

* : Significantly higher than non-athletic group ($p<0.05$).

Table 4.2 : Mean (standard deviation) peak torque results .

Subject	Extension peak torque (Nm)			Flexion peak torque (Nm)		
Groups	60 deg/sec	90 deg/sec	120 deg/sec	60 deg/sec	90 deg/sec	120 deg/sec
Non-athletic	286 (67)	263 (58)	235 (55)	206 (42)	195 (37)	187 (33)
Badminton	368 (34)	392 * (37)	381 * (41)	249 (26)	248 (24)	243 * (22)
Squash	352 (64)	348 * (53)	320 * (42)	256 (38)	260 * (42)	249 * (35)
Cycling	329 (50)	321 (44)	292 (45)	216 (29)	216 (25)	211 (22)
Rowing	389 * (82)	367 * (79)	356 * (53)	287 * (48)	278 * (47)	262 * (41)
Canoeing	350 (47)	337 * (42)	319 * (39)	304 *∇ (30)	294 *∇ (29)	284 *∇ (26)

* : Significantly higher than non-athletic group ($p<0.05$) .
∇ : Significantly higher than cycling group ($p<0.05$) .

Table 4.3 : Mean (standard deviation) peak torque / body weight ratio results .

Subject Groups	Extension peak torque / body weight ratio (%) 60 deg/sec	90 deg/sec	120 deg/sec	Flexion peak torque / body weight ratio (%) 60 deg/sec	90 deg/sec	120 deg/sec
Non-athletic	464 (75)	428 (69)	384 (80)	335 (48)	319 (45)	305 (40)
Badminton	595 (61)	634 *⊕ (75)	616 *⊕ (73)	400 (29)	399 * (28)	391 * (23)
Squash	500 (136)	519 (102)	480 (97)	380 (55)	384 * (48)	369 * (48)
Cycling	522 (77)	510 (71)	464 (77)	341 (38)	342 (33)	334 (34)
Rowing	543 (110)	511 (104)	497 * (66)	400 (61)	388 * (59)	365 * (51)
Canoeing	511 (79)	490 (60)	465 (66)	442 *∇ (44)	428 *∇ (39)	414 *∇ (35)

* : Significantly higher than non-athletic group ($p<0.05$) .
∇ : Significantly higher than cycling group ($p<0.05$) .
⊕ : Significantly higher than canoeing group ($p<0.05$) .

Table 4.4 : Mean (standard deviation) work and total work results .

Subject	Extension				Flexion			
	Work (joules)			Total Work (joules)	Work (joules)			Total Work (joules)
Groups	60 deg/sec	90 deg/sec	120 deg/sec	120 deg/sec	60 deg/sec	90 deg/sec	120 deg/sec	120 deg/sec
Non-athletic	258 (50)	232 (48)	202 (46)	2990 (667)	219 (40)	200 (38)	183 (34)	3071 (621)
Badminton	397 * (42)	378 * (36)	348 * (34)	6074 *⊕ (768)	275 (25)	264 * (23)	243 * (12)	4181 * (257)
Squash	345 * (63)	342 * (57)	303 * (46)	5362 * (910)	273 (44)	264 * (45)	248 * (41)	4368 * (662)
Cycling	319 (53)	298 (47)	268 * (47)	4653 * (634)	241 (35)	223 (36)	209 (32)	3736 (640)
Rowing	387 * (65)	373 * (74)	352 *∇ (56)	6445 *⊕∇ (1046)	297 * (55)	281 * (56)	274 *∇ (42)	4953 *∇ (795)
Canoeing	333 * (47)	318 * (40)	290 * (29)	4633 * (573)	329 *∇ (33)	307 *∇ (32)	289 *∇ (29)	5116 *∇ (574)

* : Significantly higher than non-athletic group ($p<0.05$) .
∇ : Significantly higher than cycling group ($p<0.05$) .
⊕ : Significantly higher than canoeing group ($p<0.05$) .

Table 4.5 : Mean (standard deviation) work / body weight ratio results .

Subject Groups	Extension work / body weight ratio (%)			Flexion work / body weight ratio (%)		
	60 deg/sec	90 deg/sec	120 deg/sec	60 deg/sec	90 deg/sec	120 deg/sec
Non-athletic	421 (56)	378 (57)	330 (62)	356 (42)	326 (41)	299 (37)
Badminton	640 *⊕ (64)	611 *⊕∇ (71)	562 *⊕∇ (55)	443 * (29)	426 * (29)	392 * (9)
Squash	513 (101)	510 * (107)	455 * (99)	405 (59)	392 * (65)	368 * (64)
Cycling	507 (89)	473 * (76)	426 * (79)	381 (43)	353 (48)	330 (43)
Rowing	540 * (85)	521 * (96)	492 * (71)	415 (73)	393 * (74)	382 * (55)
Canoeing	488 (85)	463 * (50)	424 * (47)	480 *∇ (52)	447 *∇ (42)	421 *∇ (38)

* : Significantly higher than non-athletic group ($p<0.05$) .
∇ : Significantly higher than cycling group ($p<0.05$) .
⊕ : Significantly higher than canoeing group ($p<0.05$) .

Table 4.6 : Mean (standard deviation) tnerk flexion / extension peak torque and work ratios results .

Subject	Peak torque ratio (%)			Work ratio (%)		
Groups	60 deg/sec	90 deg/sec	120 deg/sec	60 deg/sec	90 deg/sec	120 deg/sec
Control	72.7 (11.1)	75.1 (12.0)	81.4 (15.7)	84.9 (11.0)	86.8 (12.9)	92.2 (15.8)
Badminton	67.0 (5.9)	63.2 (7.9)	63.4 (7.7)	69.0 (3.8)	68.8 (5.8)	69.6 (5.6)
Squash	73.7 (14.8)	75.0 (11.1)	78.1 (12.8)	79.0 (17.4)	77.7 (13.1)	81.9 (13.2)
Cycling	66.1 (13.3)	68.6 (14.9)	73.4 (14.7)	77.1 (19.4)	76.1 (18.9)	79.4 (18.9)
Rowing	74.7 (12.0)	77.3 (15.1)	73.7 (11.4)	76.9 (10.9)	76.0 (12.2)	78.4 (14.5)
Canoeing	87.9 *∇ (17.5)	87.9 □ (13.8)	90.0 (15.6)	96.6 □ (16.2)	97.0 □ (14.3)	99.9 □ (14.0)

* : Significantly higher than non-athletic group ($p<0.05$) .
∇ : Significantly higher than cycling group ($p<0.05$) .
⊕ : Significantly higher than canoeing group ($p<0.05$) .
□: Significantly higher than badminton group ($p<0.05$) .

Table 4.7 : Correlation coefficients of body weight and lean body weight with peak torque and work measures for non-athletic group .

Subject	Body weight (Kg)			Lean body weight (Kg)		
Groups	60 deg/sec	90 deg/sec	120 deg/sec	60 deg/sec	90 deg/sec	120 deg/sec
Extension peak torque	0.6981 ($p<0.05$)	0.6849 ($p<0.05$)	0.4973 ($p<0.05$)	0.7203 ($p<0.05$)	0.7067 ($p<0.05$)	0.5261 ($p<0.05$)
Flexion peak torque	0.6754 ($p<0.05$)	0.6571 ($p<0.05$)	0.6428 ($p<0.05$)	0.6172 ($p<0.05$)	0.6319 ($p<0.05$)	0.6181 ($p<0.05$)
Extension work	0.7044 ($p<0.05$)	0.6719 ($p<0.05$)	0.5539 ($p<0.05$)	0.7668 ($p<0.05$)	0.7383 ($p<0.05$)	0.6007 ($p<0.05$)
Flexion work	0.7646 ($p<0.05$)	0.7363 ($p<0.05$)	0.7158 ($p<0.05$)	0.7340 ($p<0.05$)	0.7259 ($p<0.05$)	0.6938 ($p<0.05$)

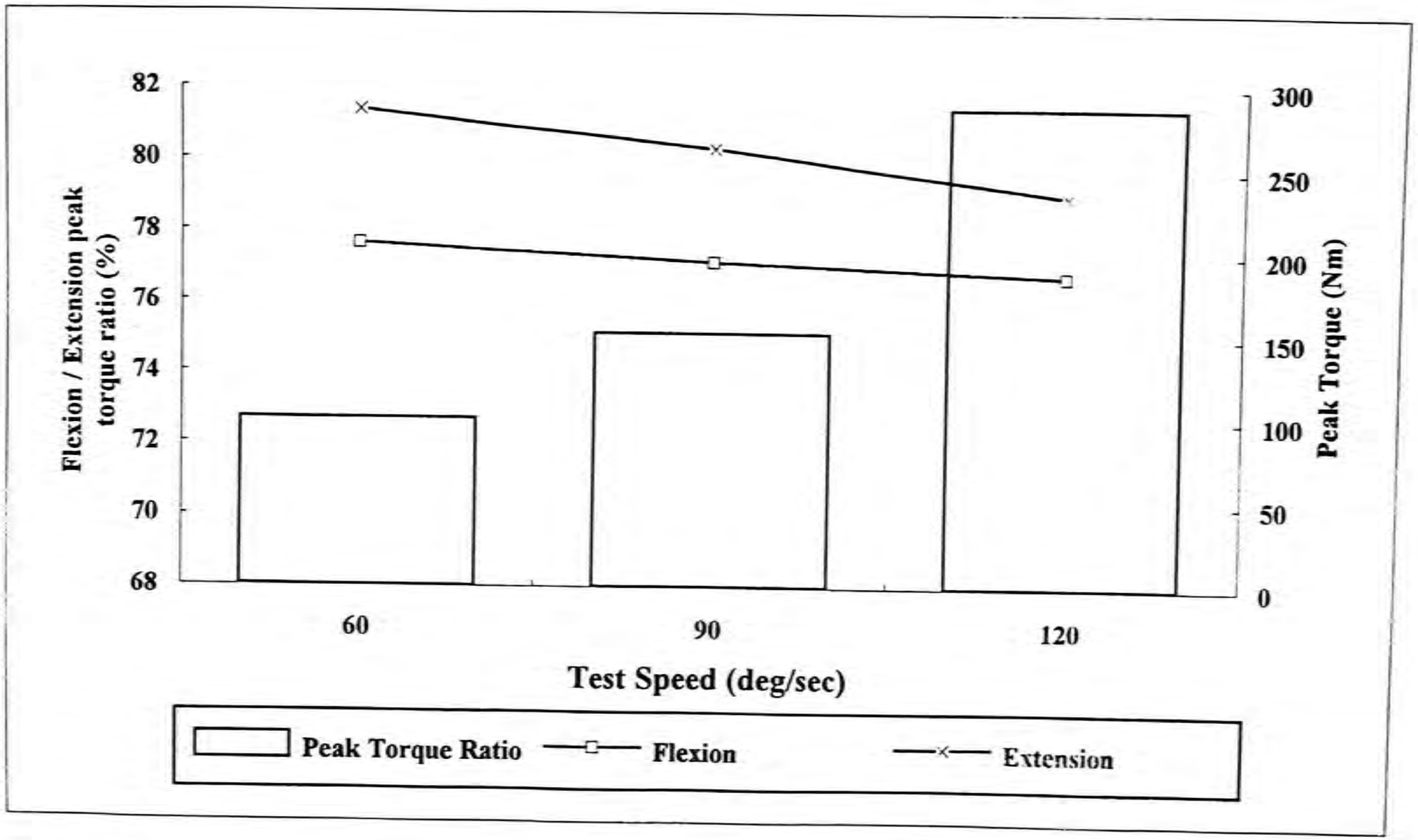


Fig 4.1. Peak torque results in non-athletic group .

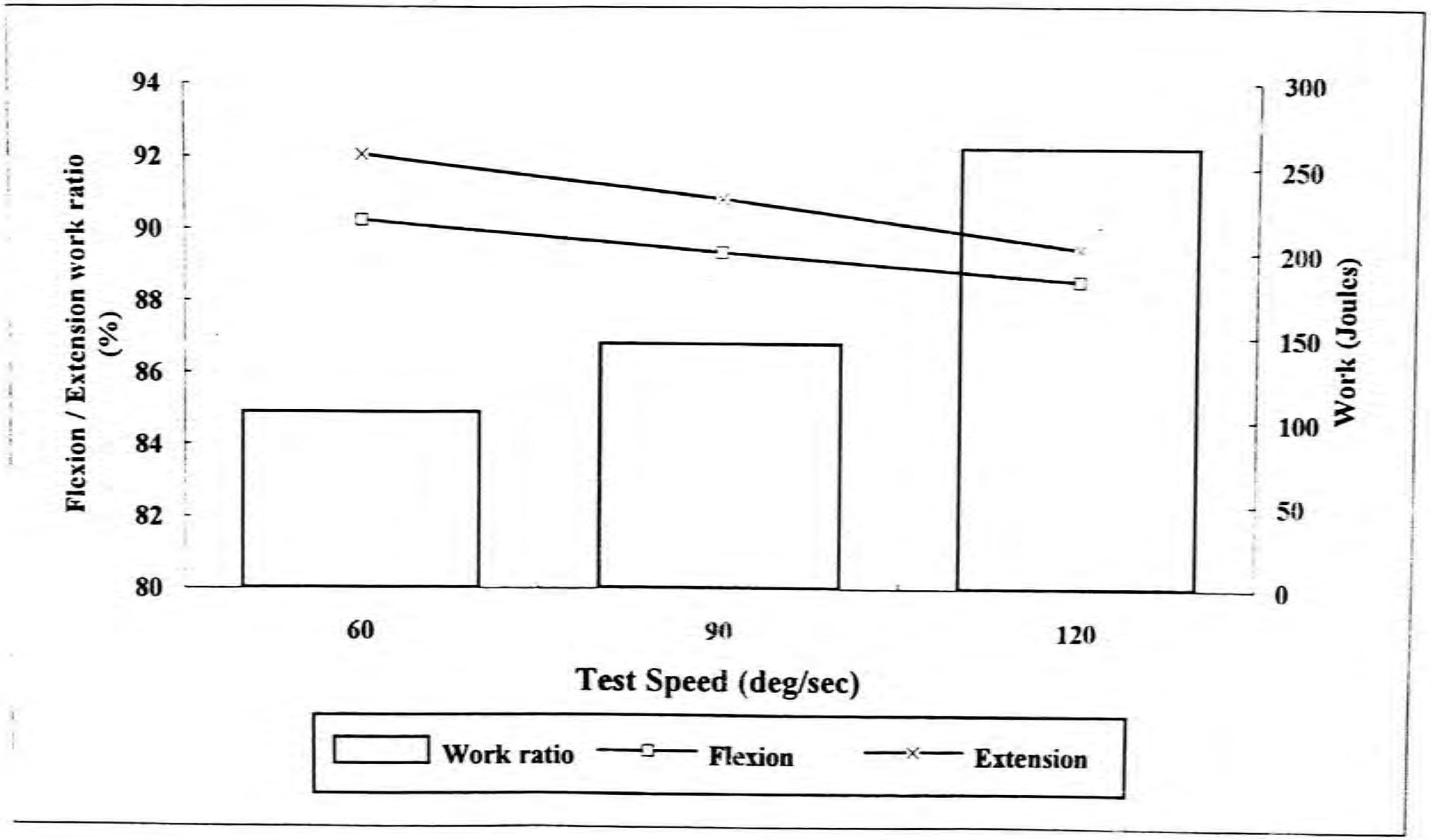


Fig 4.2. Work results in non-athletic group .

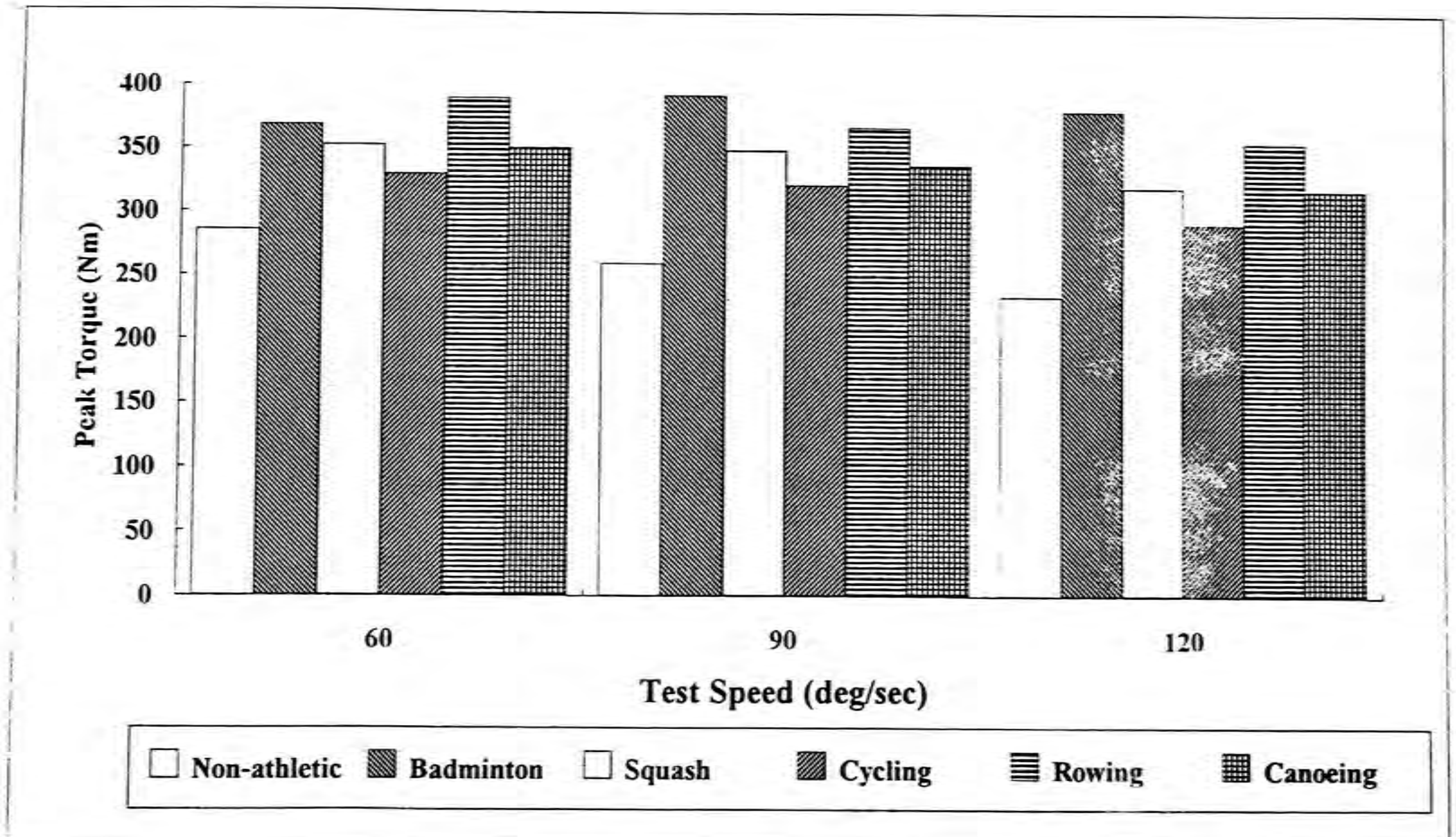


Fig 4.3. Extension peak torque results .

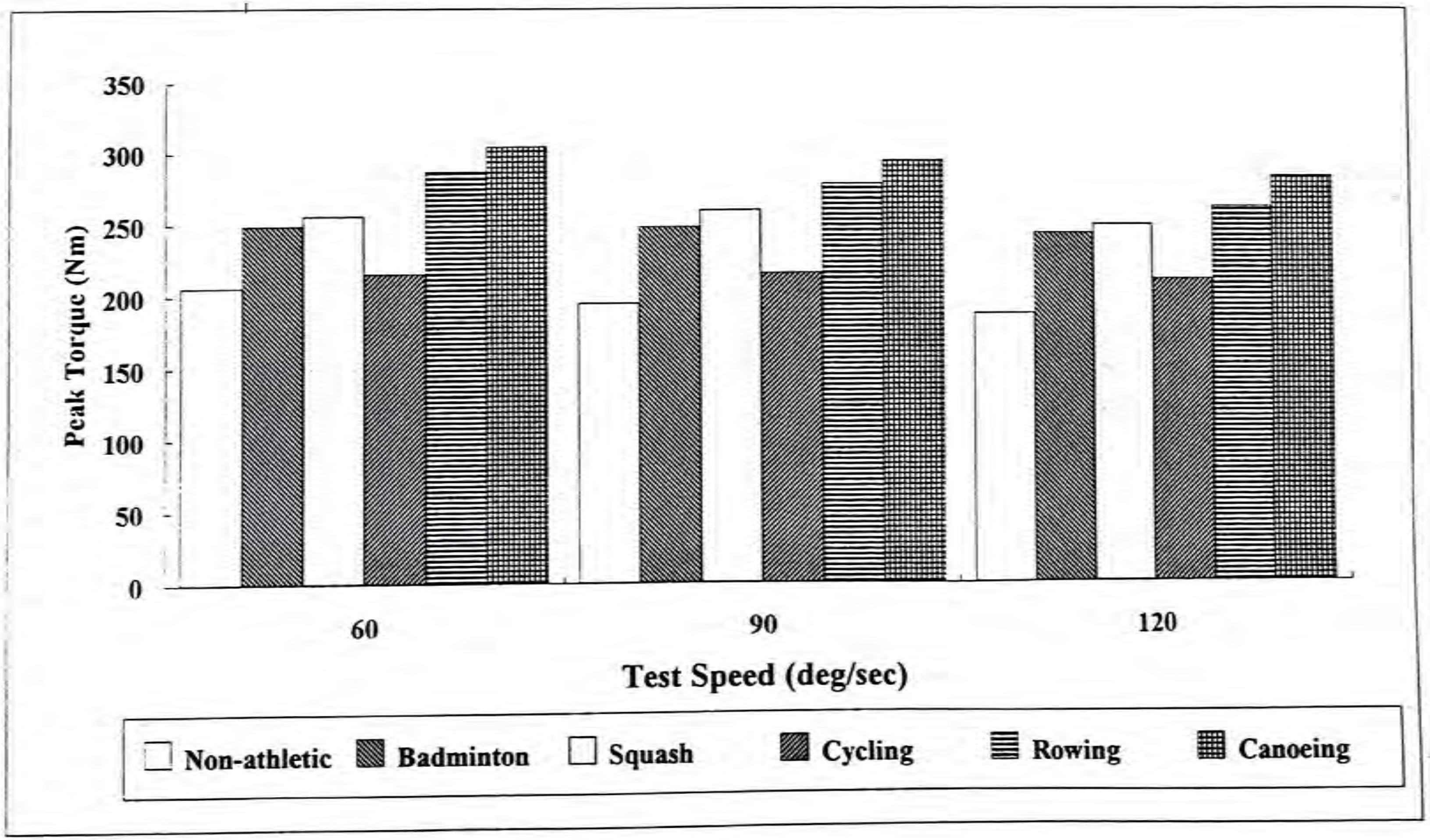


Fig 4.4. Flexion peak torque results .

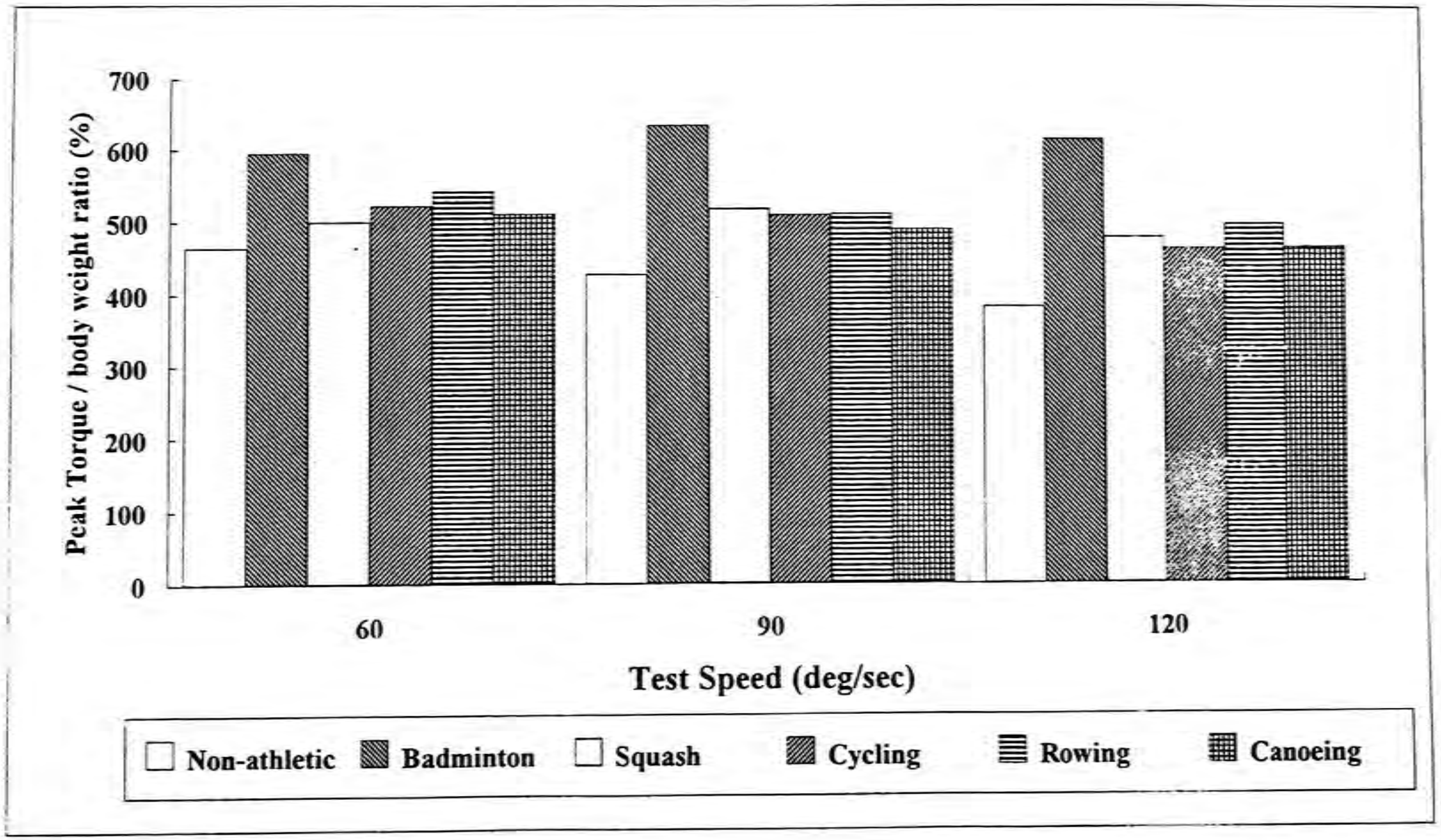


Fig 4.5. Extension peak torque / body weight ratio .

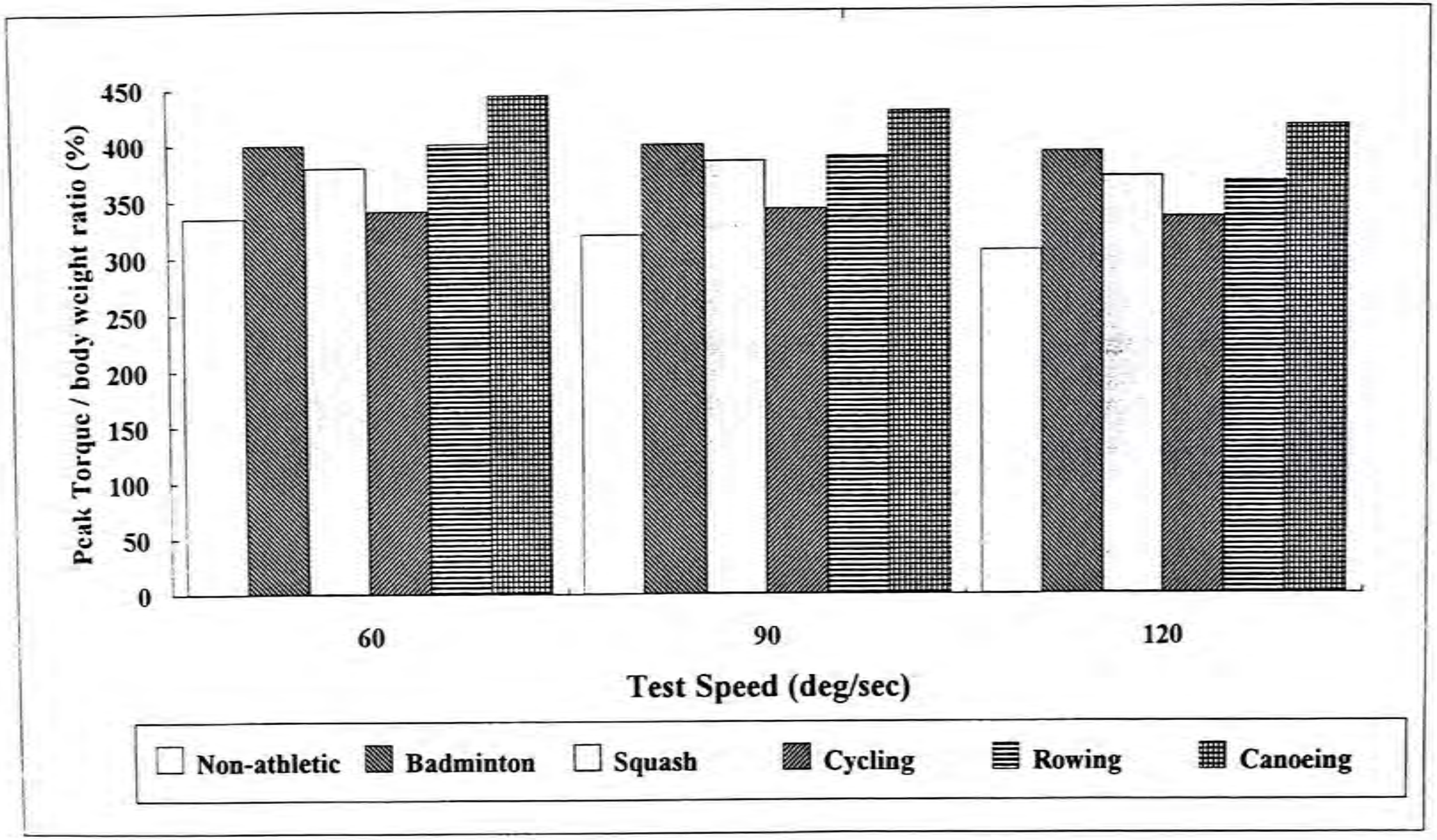


Fig 4.6. Flexion peak torque / body weight ratio .

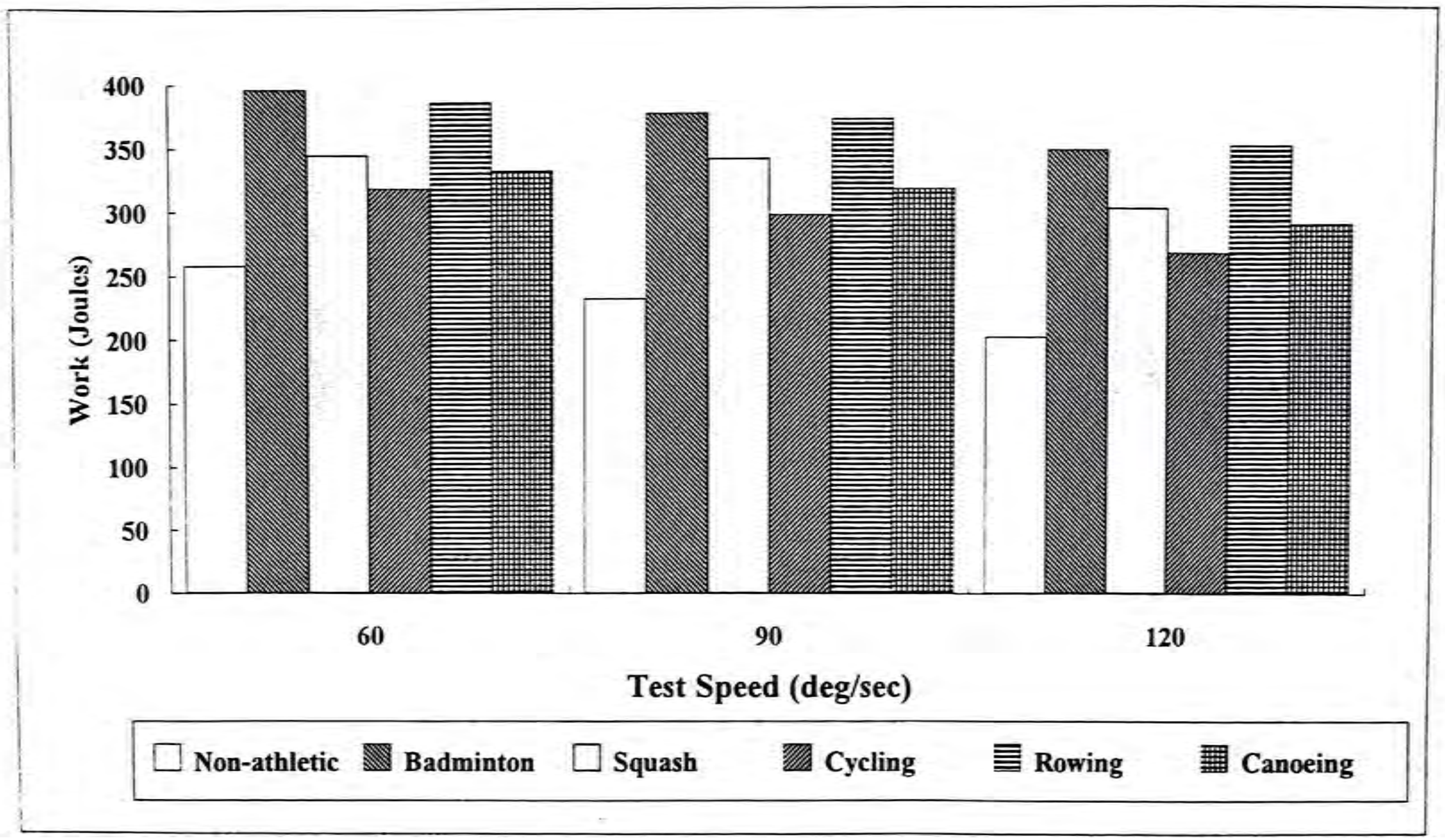


Fig 4.7. Extension work results .

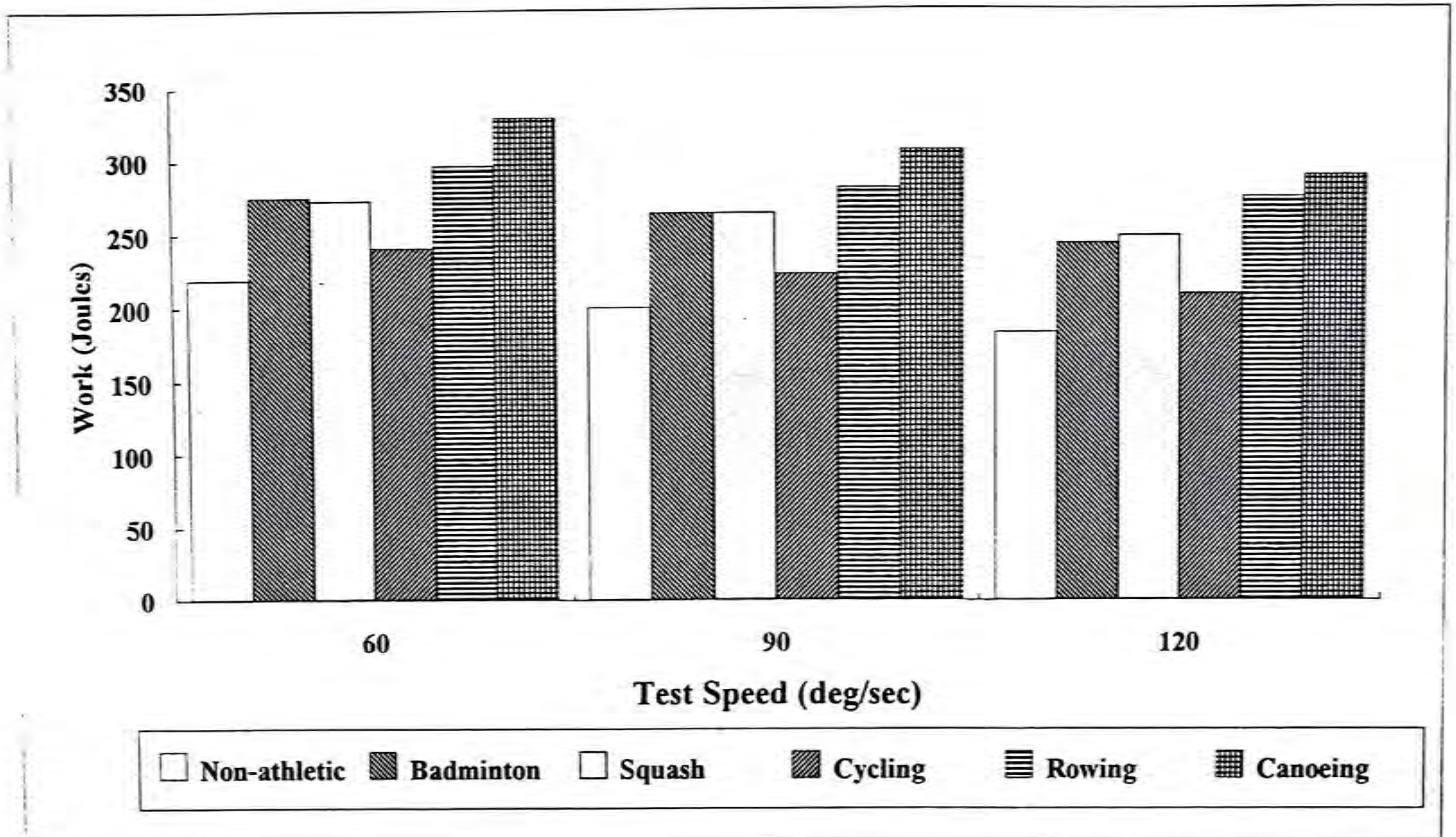


Fig 4.8. Flexion work results .

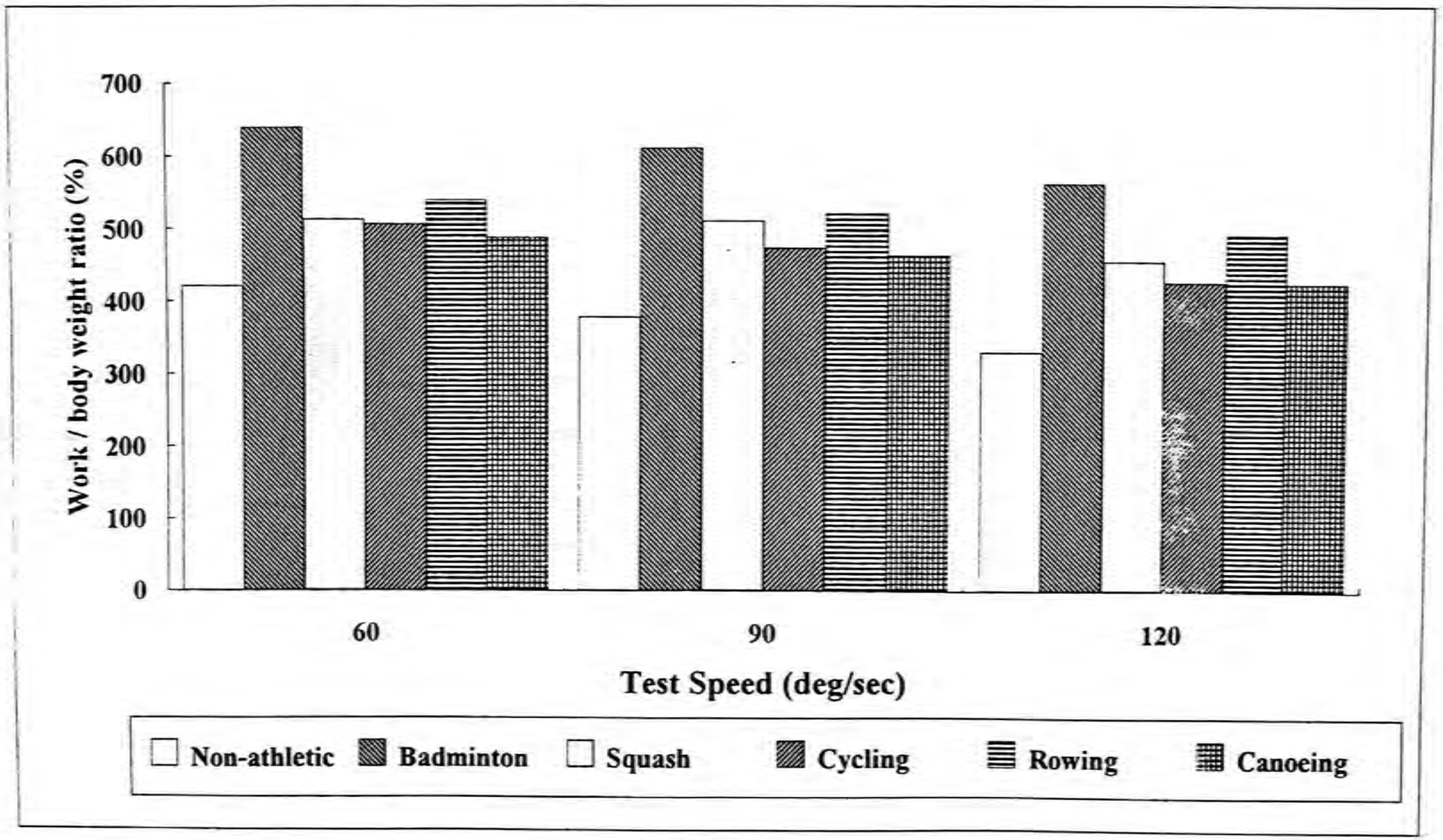


Fig 4.9. Extension work body weight ratio .

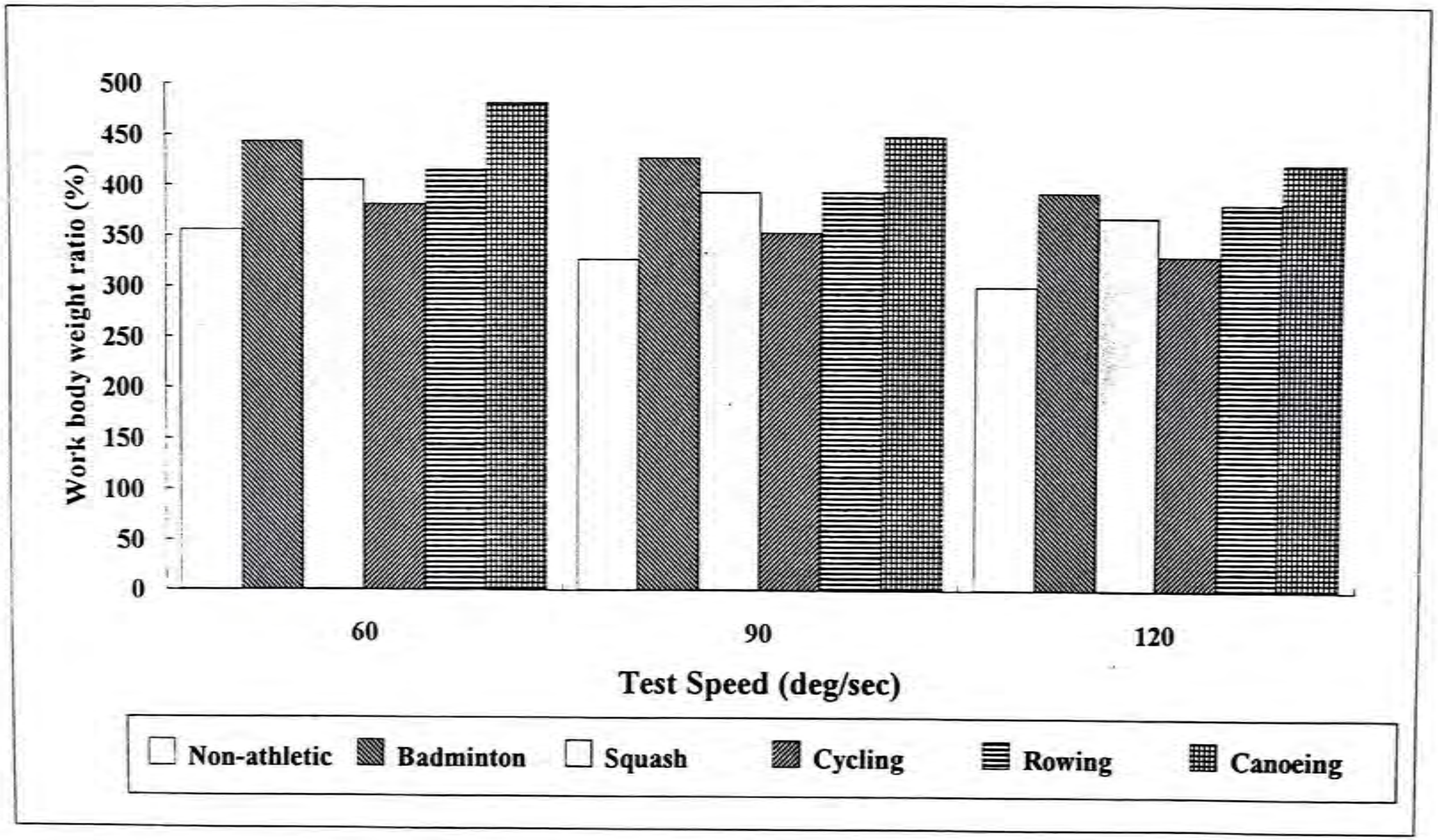


Fig 4.10. Flexion work / body weight ratio .

V. DISCUSSION

It is well established that isokinetic muscular characteristics of a particular sporting event reflect the specific characteristics and requirement of that event (63, 66, 67, 74, 75, 76). Likewise, it is reasonable to hypothesize that specific muscular characteristics could be developed in the trunk extensor and flexor. This is supported by Langrana et al (19), who found that peak torque tests of professional ballet dancers having trunk extension values higher than those reported for non-dancers and semi-professional dancers. They postulated that the differences in training hours between the groups might explain the superior strength levels demonstrated by the professional dancers.

Hasue et al (7) stated that there was a tendency for both abdominal and back muscles to become weaker in advancing age and this tendency was apparent only after age 40 years. By multiple regression, Nachemson and Lindh (26) found that the variables "trunk extension strength" and "abdominal strength" were independent of age (from 20-55 yrs). In the present study, all subjects were between 17-33 yrs. The literature provides no guidance as to whether age below 20 would be an important factor for trunk extension and flexion performance. In addition, analysis of covariance in this study suggests that age had no effect on the isokinetic performance of non-athletes. Moreover, there were no significant differences in the respective heights of subjects in the six tested groups. It was thus concluded that age and height were unlikely to influence the results.

It has been found that the individual measurements of static back and abdominal strength are significantly related to subjects' weight, particularly for male subjects (29). From the analysis of body weight and lean body weight in the non-athlete group, it was found that both body weight and lean body weight were highly correlated ($p<0.05$) with peak torque and work measures at all tested speeds. Smith et al (12) have previously stated that torque divided by body weight has traditionally been used to standardize torque data. The high correlation between torque to body weight and torque to lean body weight found in the present study indicates that this latter measure is not necessary. Torque can be accurately standardized by either body weight or by lean body weight; but body weight is more readily available. There were no statistically significant differences among tested groups in body weight measures, therefore the effect of body weight should not contribute much in the specific isokinetic performance in each group. However, relative value of peak torque and work measures are still presented for comparison.

5.1 Isokinetic performance in Non-athletic group

As with the isokinetic results in other joint movement tests (e.g. knee extension and flexion, shoulder extension and flexion etc.), the peak torque and work results of trunk extension and flexion tests, decreased as the test speed increased. The differences found in this study were statistically significant, therefore, comparison of test results by using the Cybex TEF system, must be speed specific.

The findings of the present study show that trunk extension strength was greater than trunk flexion strength at all tested speeds. This is consistent with findings of numerous other studies including Flint (43), Suzuki and Endo (20), Hasue et al (7) and Langrana et al (19). Smith et al (12) explained that the differences might be due to the larger cross-sectional area of the trunk extensor. However, the relative superiority of the trunk extensor to trunk flexor may change as the test speed is increasing. Davies and Gould (18) found that at higher speeds (higher than 90 deg/sec), flexor strength matched and then exceeded extensor strength. In that study, the peak torque scores of trunk extension and flexion decreased as in this study. However, in Davies' study, the total peak torque decrement for the flexion test was 11% and for the extension test, 29% from 60 deg/sec to 120 deg/sec. The decrements for this study were 9% and 18% respectively. The decrement in extension was more than the decrement of the flexion test, but the extent of the decrement was more pronounced in Davies' study. Therefore, the flexion peak torque may match up with extension peak torque at higher test speeds (higher than 120 deg/sec) for the present study population, and using the Cybex TEF system.

The difference in the decrement of extension and flexion peak torque and work results with increasing test speed affected another measure - trunk flexion/extension peak torque and work ratios. The peak torque and work ratios increased with test speed. There was about 10% increased for both peak torque and work ratios from 60 deg/sec to 120 deg/sec. These were similar to the isokinetic H:Q (hamstring to quadriceps) ratio values measured at different test speeds. Several studies suggested that H:Q peak torque ratio rose significantly as the test speed increased (63-67) and the authors suggested that knee flexors apparently play a greater role in muscular balance at higher speed, while at slow speeds the quadriceps were the more dominant muscles. This suggestion can be applied to the trunk extensor and trunk flexor as the dominant role of the trunk extensor at slow test speed will be taken over by the trunk flexor as the test speed is increasing. Davies and Gould (18) also suggested such change of dominance in trunk muscles was attributed to both increased inertia and the balanced muscle activity in antagonistic groups when speed was increasing.

5.2 Difference between athlete categories

Although the training programs and strength demands in different sports vary considerably, some general trends were present when comparing the strength of the trunk muscle between the athletes and the untrained subjects. Fenety and Kumar (41) stated that execution of most field hockey ball handling skills requires a combination of spinal flexion and rotation. These two movements can increase the work of the back extensor muscles and the spinal compression load. Flint (43) has commented that a significant increase in abdominal and back muscle strength might be attained by use of a systematic program of progressive resistance exercise.

As expected, the athletes were stronger than non-athlete subjects. Generally, the difference was most marked in absolute peak torque and work measures. This may due to the fact that the athletes had comparatively higher body weight than normal and the isokinetic results were highly correlated with body weight (Table 4.7). Interestingly, not all athletic groups (e.g. cycling) had a significantly higher peak values than the non-athlete males. Whether the relatively low trunk muscle strength for some sports is due to the low demands of the sport or shortcomings of the training programs, cannot be concluded from the present results. In addition to the general differences between athletes and non-athletes, some results specifically related to the different sports are worth mentioning.

5.2.1 Badminton

The badminton athletes distinguished themselves from the other athletes by having the highest isokinetic performance in extension movement which was more apparent when expressed in relative values (body weight ratio). That means that, in extension, they were particularly strong which could be related to the need to extend the body in many badminton exercises, e.g. smashing and over-head playing. Generally, there was slight decrease in isokinetic peak torque results from low to high test speeds (18, 52). For badminton players tested in this study, a different pattern was found. They produced higher peak torque results in higher speed. This may due to the fact that badminton is a quick sport and their muscles are recruited and function better at high speed movement. Kumi (68) has suggested that muscle training could induce changes in neuromuscular function. This may also be the reason why badminton athletes scored significantly higher results at higher test speeds in both trunk extension and flexion test. Consequently, more training at fast speed (higher than 90 deg/sec) is desirable for badminton athletes. They were no longer the dominant group in trunk flexion test. Although they were still significantly better than the non-athlete group, the badminton players were no longer the dominant group in trunk flexion values. This may infer that the training effect of badminton on flexor muscles is similar to the other sports..

5.2.2 Squash

This sport is similar to field hockey in the way that it also requires a combination of spinal flexion and rotation. In addition to these movements, a lot of trunk extension movement is also required. Therefore, squash players were not just good in trunk extension strength (41), they were also good in trunk flexion capacity. The present study showed that these elite squash athletes had attained lower extension values than badminton and lower flexion values than the canoeists. Therefore the goal of squash training should aim at an optimum muscle strength and endurance on their trunk extensor and flexor.

5.2.3 Cycling

Cycling athletes do not spend much time on pure trunk muscle training. Moreover, the sport itself does not stress the trunk muscles much because the upper bodies are supported by the handles. Most of the stress is on the shoulder muscles. Cycling athletes scored significantly higher results than non-athlete only in high speed work and total work measures in trunk extension test. This can be explained by the nature of the sport. Cycling is an endurance sport, the high working capacity of the quadriceps is documented as an important contributor for a good cyclist (69). Therefore, there may be cross over training effect to other muscle group including the trunk muscles. Without direct stimulation from muscle training and sport specific training of the trunk muscles, high muscle strength results, measured isokinetically, cannot be expected. No wonder the cyclists scored the lowest flexor and extensors values among the five tested groups.

5.2.4 Rowing

One of the important muscle group for generating power for propelling in rowing are the back extensors. Therefore good rowers are expected to have very strong back extensor. In this study strength capacity of rowers was just lower than that of the badminton players. But for other measures, total work and work (120 deg/sec), this group had the highest score in extension movement. Rowers have to extend the back strongly in each stroke, and the whole race may take more than six minutes to finish. Therefore, the total work capacity of the back extensor is a critical factor for a rower. In contrast, trunk flexor had lower work capacity in comparison to their back extensor, because their top position was replaced by other sports, especially as body weight was taking into account. This may be due to fact that rowers are relaxing their trunk muscles as they return to the flexed position and the stress on abdominal muscles will be reduced. It seems that their trunk flexor do not involve too much in rowing, but the muscle training on this muscle group cannot be neglected. The results of Hong Kong rowing team's flexor was not the best, but they were still higher than many other tested groups e.g. cyclists and squash.

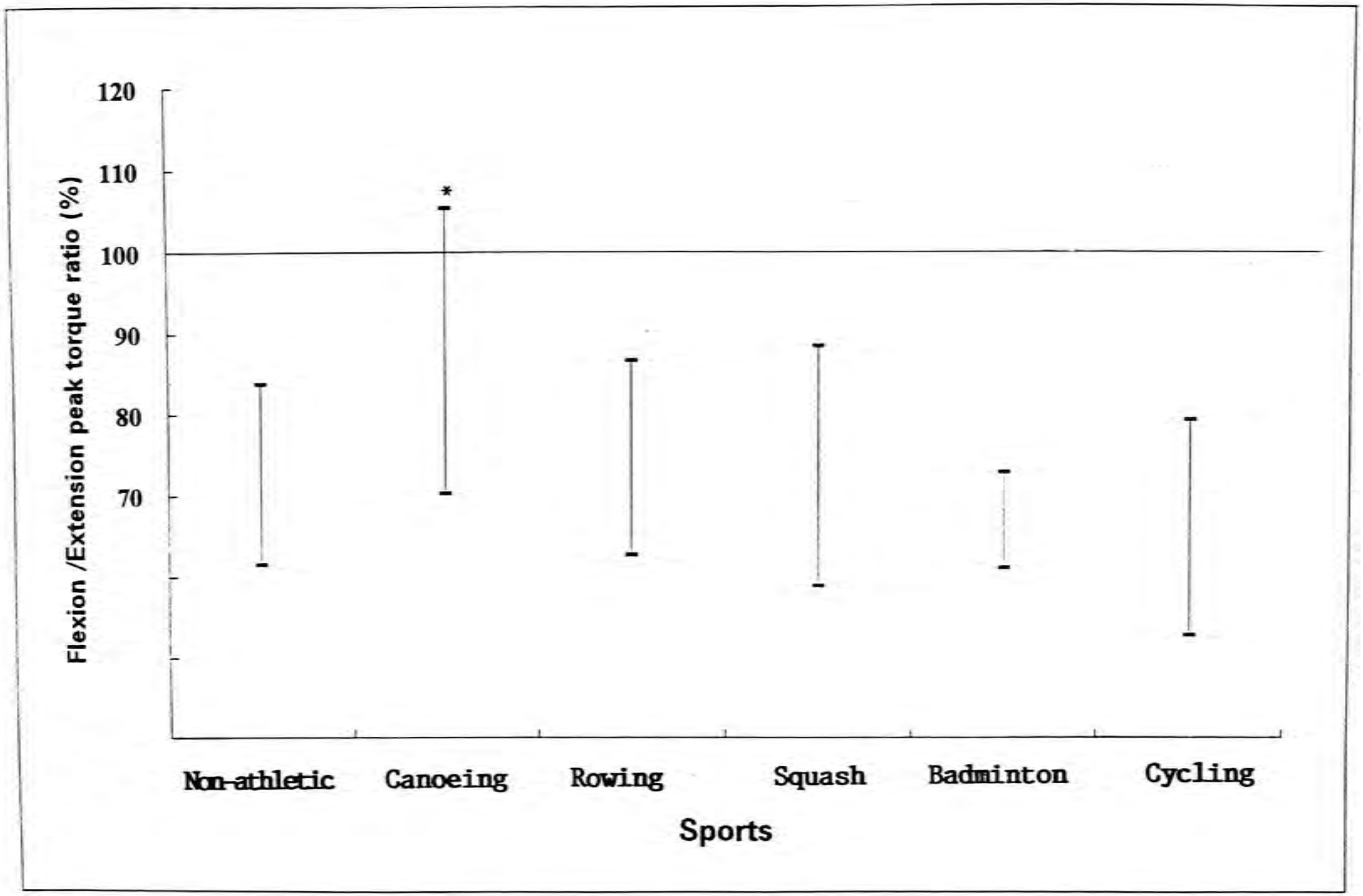
5.2.5 Canoeing

This group was the best group in the trunk flexion test. On the other hand, their extension results were just significantly higher ($p<0.05$) than the non-athletic group and were comparatively lower than other sport groups. Their results from trunk extension and flexion tests were about the same. Apparently, canoeing imposed great stress on their trunk flexor, so much so that their trunk flexor to extensor ratio approached 100%. Therefore, the balance of the trunk extensors and flexors is an important characteristics for canoeists, as they need to keep the body in straight position during sculling. If the abdominal muscles are too strong, they will lean forward and on the other hand, if they have too strong back extensors, they will lean backwards.

5.3 Strength imbalances and back problem

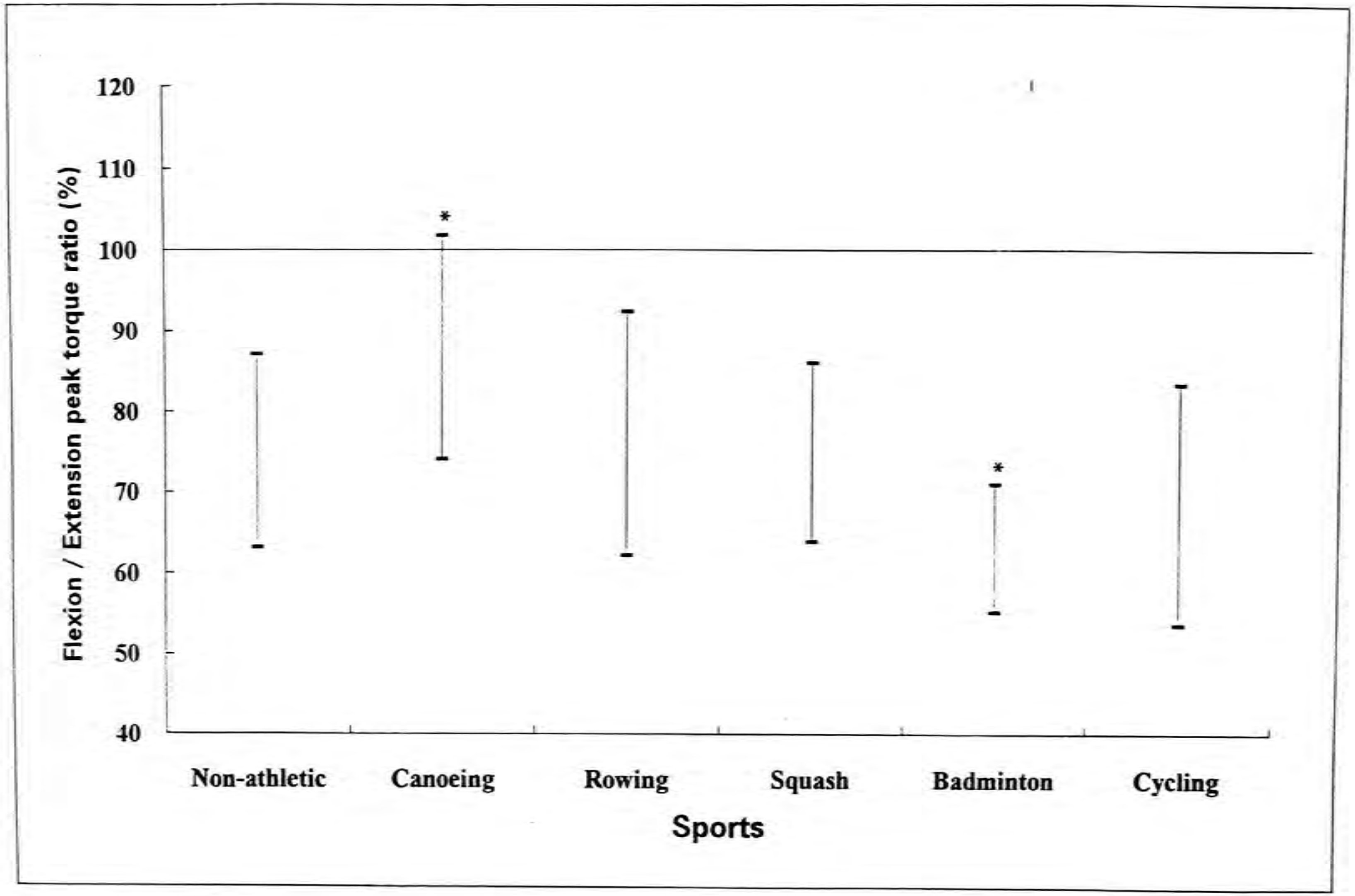
For the trunk flexion/extension peak torque ratios, these ratios generated from the isokinetic test can be used to assess muscular strength imbalance. The ratios of antagonist to agonist muscle groups (flexor to extensor) is used to determine ipsilateral muscle balance. Flint (43) found that the relief from chronic low back pain symptoms might be felt when the strength imbalance between the back extensor and trunk flexor was reduced. As stated before, many studies had been done to identify the trunk flexion/extension peak torque ratio that was supposed to be normal or clinically healthy. But the methods and apparatus used vary widely, and comparisons cannot be made. Therefore, this study can serve as descriptive study in providing clinical guidelines for testing and rehabilitation.

The selective increase of the strength and work capacity of trunk extensors or trunk flexors in the athletes resulted in agonist and antagonist ratios which were at variance with those of non-athlete (Fig. 5.1, 5.2, 5.3). By paired t-test, each sport group compared their flexor/extensor peak torque ratios with the non-athletic group's. The canoeing group was significantly higher ($p<0.05$) than the non-athletic group at 60 deg/sec and 90 deg/sec tests, while the badminton group was significantly lower ($p<0.05$) than the non-athletic group at 90 deg/sec and 120 deg/sec tests. The other three sport groups were not significantly different with the non-athletic group. But by comparison, the squash was the group mostly similar to the non-athletic group in flexion/extension peak torque ratios. The cycling group was far more lower and the rowing was right between squash and cycling groups. Therefore, it seemed that only squash group, or together with rowing group had their peak torque ratios similar to non-athletic group's. Such imbalances in trunk muscle strength have been put forward as possible factors in the etiology of low back pain (19, 40, 43). However, in the case of back patients, the abnormal ratios were due to specific weakness of trunk muscles. In the athletes, they were caused by specific increase in the strength of trunk muscles. Both groups, back patients and athletes, had their ratios different from the normal. Whether the athletic group will be more prone to having back problems than the back patients cannot be concluded for the present results. Further study must be carried out on this aspect.



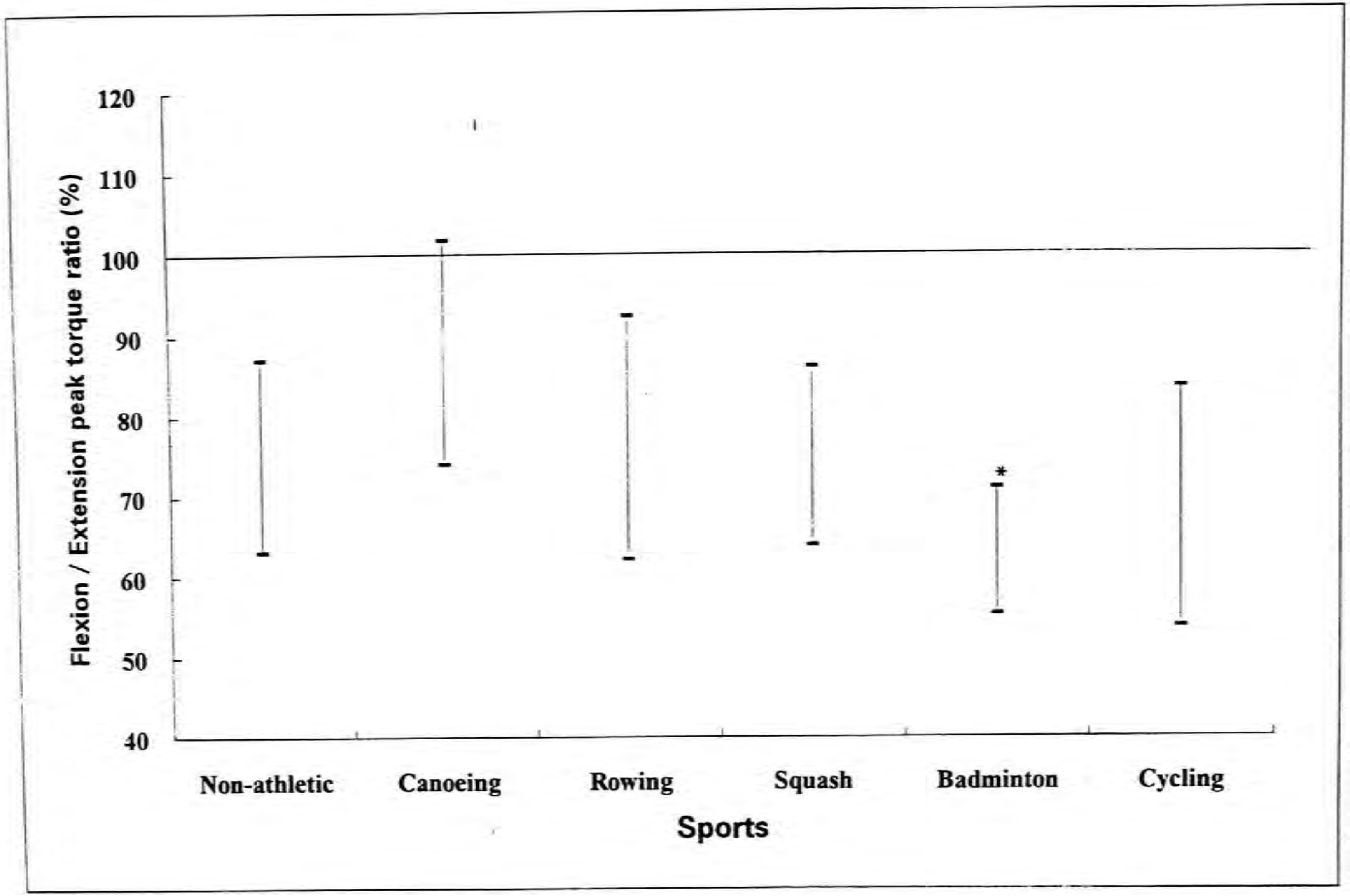
Fige 5.1. Mean values (± 1 SD) for flexion / extension ratios in peak torque at 60 deg/sec .

* : Significant differences for the athletic groups as compared to the non-athletic group ($p<0.05$) .



Fige 5.2. Mean values (± 1 SD) for flexion / extension ratios in peak torque at 90 deg/sec .

* : Significant differences for the athletic groups as compared to the non-athletic group ($p<0.05$) .



Fige 5.3. Mean values (± 1 SD) for flexion / extension ratios in peak torque at 120 deg/sec .

*** : Significant differences for the athletic groups as compared to the non-athletic group ($p<0.05$) .**

5.4 The discrepancy of the Cybex test

Although the isokinetic test is an objective, reliable and reproducible test, the Cybex isokinetic dynamometer has certain limitations. They include the following :

(A) Adaptation discrepancy

Isokinetic is an unnatural movement because the speed is constant. Muscles have to 'learn' to perform it well. Therefore, subjects must have enough trials on the isokinetic dynamometer before each test. Usually five submaximal repetitions are good enough for the muscle to adapt to such movement pattern, but some subjects may be required to do more repetitions before they can familiar with the test. The tester must teach the subjects how to move with the isokinetic dynamometer.

(B) Unstandardized verbal encouragement

(C) Position of testing not natural

Usually tested athletes complained that the awkward movement was not natural to their sports.

(E) No eccentric control

5.5 The methodology - Control of subjects

(A) Athlete groups:

- Because the athletes participating in this study were restricted to Hong Kong National team members during the year of testing, the number of athletes in each sport was quite small. For example, only five athletes were in badminton group. Therefore, each athlete contributed greatly to the group mean. Although testing time was arranged in the mid-season of each sport group, the physical condition, psychological condition and fitness level might be different. Such differences might affected the test scores. Therefore, more testing for more subjects must be done to identify clearly their specific muscular characteristics. Statistical modeling is one of the methods of using the limited elite athletes data to build up some models to describe the specific physical and physiological characteristics of different sports. This is a study to be followed in Sports Science Department of Hong Kong Sports Institute.

(B) Non- athletic group

Subjects in control group came from a wide range of faculty. Half of them were high school students. Although none of them had received any of regular sports training, some of them (n=6) were very active, they exercised two or three days per week. Thirty of them seldom exercised, and 19 of them performed in average one to two hours exercise per week. Therefore control group represented a group of people with large spectrum of fitness level.

VI. CONCLUSION

The isokinetic test results support the hypothesis of this project that trunk muscle characteristics of elite male athletes of different sports measured isokinetically were different among the sports tested.

The difference in test results correlate well with the muscle involvement in the sport and general life activities. The isokinetic test by using Cybex TEF system is a sensitive test to assess the muscular characteristics of athletes. As only a small number of athletes participated in this investigation, larger scale investigations must be done to identify the isokinetic muscular characteristics among different sports in the trunk extension and flexion movements.

APPENDIX A

INFORMED CONSENT FOR A CYBEX TRUNK MUSCLE TEST

INTRODUCTION

The objective of this research is to find out what are the trunk extensor and flexor characteristics of the Hong Kong elite male athletes. According to the past findings, 3 hypothesis can be made for the Hong Kong elite athletes who participate in isokinetic trunk muscle test.

i) The trunk muscular characteristics are different among the athletes because of different sporting events.

ii) The trunk muscular characteristics of each sporting event will reflect the specific characteristics and requirement of that particular sporting event.

iii) The specific muscular characteristics will contribute to the success of the athletes in each sporting event.

The sports that are going to compared are badminton, canoeing, squash, rowing and cycling. In addition to compare the testing results within these sports, comparison with the normal, healthy and young people are also crucial for this project (to see the differences between the elite athletes and the normal people). Therefore, your contributing is very helpful and important.

EXPLANATION OF THE CYBEX TEST

You are required to come to the Human Performance Laboratory of the Hong Kong Sports Institute once. During your visit, you will perform a trunk extension and flexion test on the Cybex TEF^{TM} (trunk extension and flexion) system. In this muscle test, you will perform 4 repetitions at low (60 deg/sec) and medium (90 deg/sec) speeds to test your muscle strength, and do 20 repetitions at high (120 deg/sec) speed to test your muscle endurance. In each repetition, you must exert all your effort.

INFORMED CONSENT FOR A CYBEX TRUNK MUSCLE TEST

I have read this form and I understand the test procedures that I will perform. I consent to participate in this test.

____

Signature

_______________________ _______________________

Date Witness

Questions :____

____

CONFIRMATION

Do you have any cardiovascular, neuromuscular and back muscle problems in the past three years ?

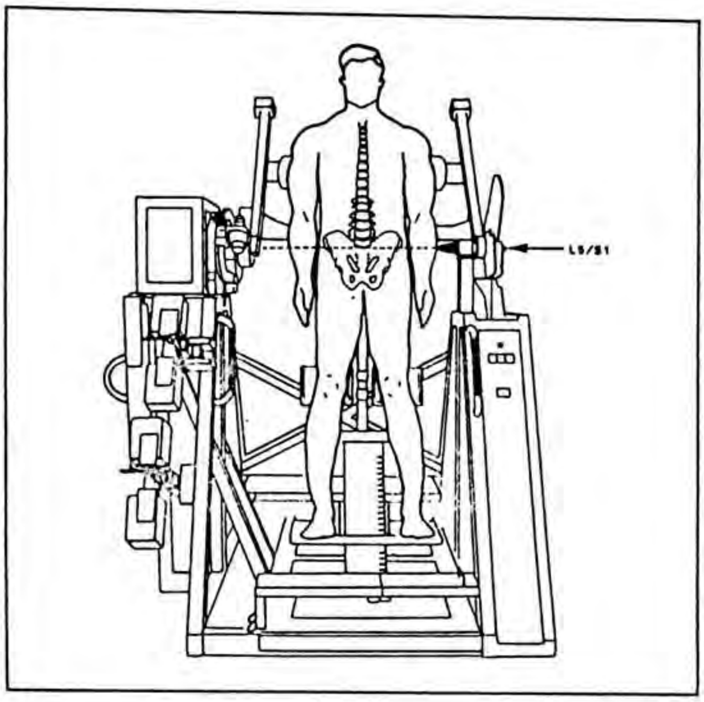
If yes, what are the problems ?_______________________________

APPENDIX B

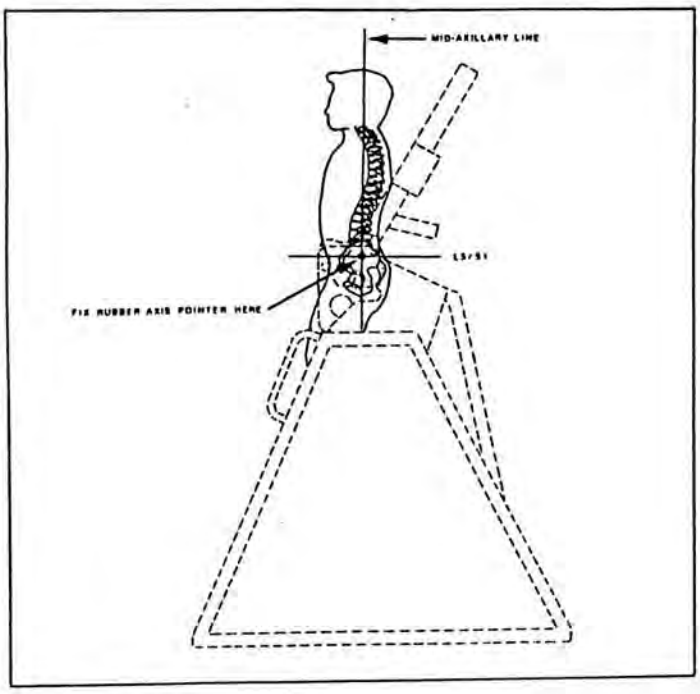
Picture List :

PICTURE 1

PICTURE 2



PICTURE 3



PICTURE 4

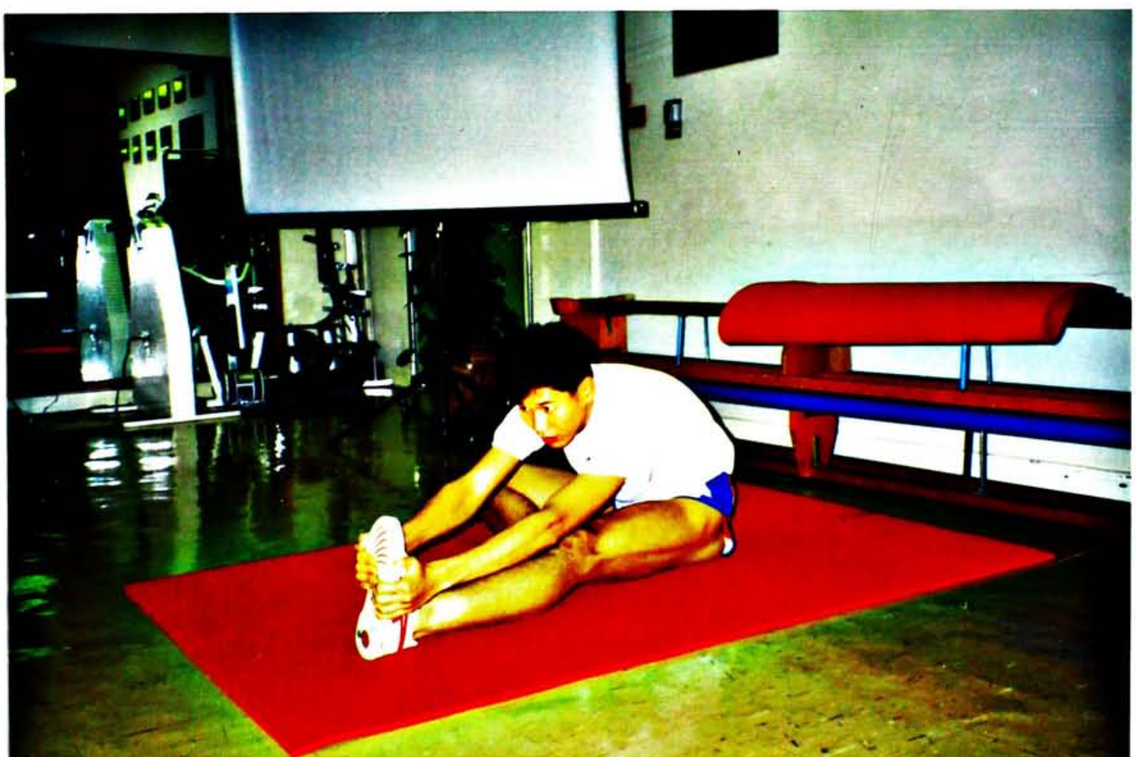
PICTURE 5

PICTURE 6

PICTURE 7

PICTURE 8

PICTURE 9

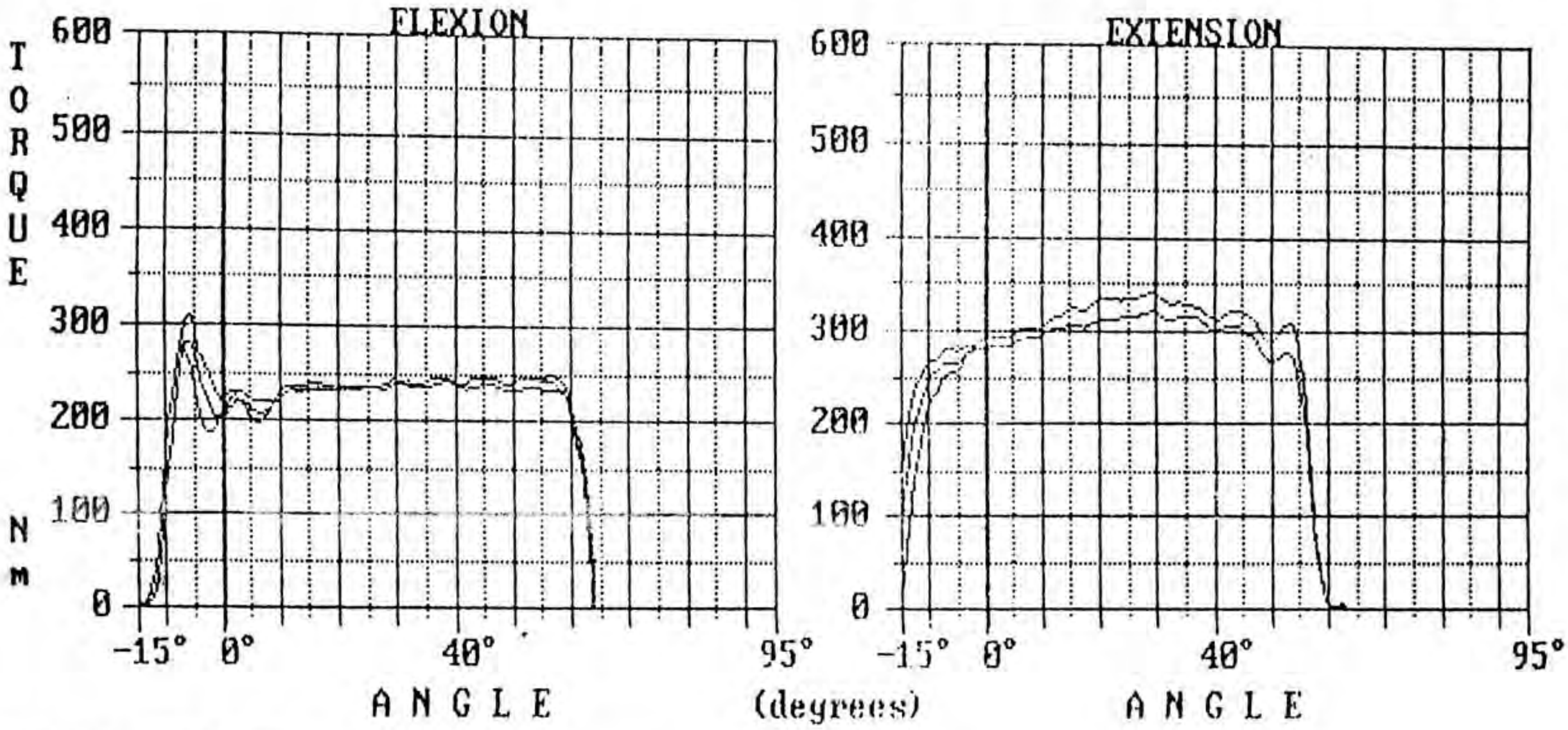


PICTURE 10

CYBEX ISOKINETIC TEST EVALUATION
HONG KONG SPORTS INSTITUTE
PATIENT: WAI HO . CHU 00383

TRUNK EXTENSION/FLEXION
INITIAL REPORT
BODYWEIGHT 60 Kg

SPEED 60 DEG/SEC LEGEND: TEST1 average points, maximum points, best work



CYBEX TEST DATE(S)	2/24/1994		
SPEED (deg/sec)	60	90	120
EXTENSION			
PEAK TORQUE (Nm)	309	298	283
PEAK TORQUE %BW	565%	496%	471%
TOTAL WORK(BWR,J)	363	326	302
TOTAL WORK (BWR) %BW	605%	543%	503%
AVG.POWER (BWR,WATTS)	281	383	454
AVG.POWER (BWR) %BW	468%	638%	756%
AVG.POINTS VARIANCE	8%	12%	12%
TAE (J)	77.3	109.7	104.1
TOTAL WORK SET 1(J)			4421
ENDURANCE RATIO 1			60%
TOTAL WORK SET 2 (J)			
RECOVERY RATIO			
FLEXION			
PEAK TORQUE (Nm)	244	238	234
PEAK TORQUE %BW	406%	396%	390%
TOTAL WORK(BWR,J)	288	275	272
TOTAL WORK (BWR) %BW	480%	458%	453%
AVG.POWER (BWR,WATTS)	222	318	405
AVG.POWER (BWR) %BW	370%	530%	675%
AVG.POINTS VARIANCE	9%	9%	9%
TAE (J)	61.8	92.6	119.0
TOTAL WORK SET 1(J)			4990
ENDURANCE RATIO 1			88%
TOTAL WORK SET 2 (J)			
RECOVERY RATIO			
FLEXION/EXTENSION RATIO AND ROM			
PEAK TORQUE	71%	79%	82%
TOTAL WORK (BWR)	79%	84%	90%
AVERAGE POWER (BWR)	79%	83%	89%
TOTAL WORK SET 1			112%
MAXIMUM ROM (DEGREES)	78	80	83
AVG ROM		(87)	

PICTURE 11

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